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In 1877, a society of mathematicians was established in Tokyo. Later, in 1884, the scale of the society was enlarged so as to include physicists and astronomers also, and the society was called Tokyo Mathematico-Physical Society. The word "Tokyo" was replaced by the word "Japan" in 1919, the new name being The Physico-Mathematical Society of Japan. The society had grown up into a large one with lapse of time, till, at last, it seemed more convenient to split it up into two, the mathematical and the physical, societies. This measure was actually taken in 1946, and to the latter, that is our present society, was given the name The Physical Society of Japan.

As to the publications, "Proceedings of Tokyo Mathematico-Physical Society" and "Proceedings of the Physico-Mathematical Society of Japan" were published in succession, during the period 1885—1944. The present issue, that is, "The Journal of the Physical Society of Japan" is the continuation of the physical part of the above two "Proceedings".

These two "Proceedings" contained many celebrated papers in mathematical and physical sciences, and their existence was known throughout the world. It is hoped that the "Journal" here started will also play a good part in promoting one branch of the peaceful activity of Japan. (T.S.).

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Refraction and Faraday Effect of Rare Earth Ions in Aqueous Solutions.

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(Received December 22, 1943.)

1. REFRACTION.

The specific refraction R' of a substance is defined by the formula

$$R' = \frac{1}{s} \frac{n^2 - 1}{n^2 + 2}, \dots\dots\dots(1)$$

where s is the density of the substance and n its refractive index for the light of the wave-length λ . The molecular refraction R_2 of a solute in aqueous solutions is calculated by means of the formula

$$\frac{R_2}{M} = R'_2 = \frac{1}{\tau_2} R' - \frac{\tau_1}{\tau_2} R'_1, \dots\dots\dots(2)$$

where M = the molecular weight of the solute, R' , R'_1 , R'_2 = the specific refractions of the solution, the solvent and the solute, respectively, τ_1 , τ_2 = the grams of the solvent and the solute in 1 gram of the solution.

We now make use of the data for the refractive indices of aqueous solutions of rare earth salts reported by Slack, Reeves and Peoples⁽¹⁾ (CeCl_3 for $\lambda 5893\text{\AA}$ at $26\sim 30^\circ\text{C}$) and Mason, Hickey and Wilson⁽²⁾ (PrCl_3 , SmCl_3 and EuCl_3 for $\lambda 4811$, 5086 , 5461 , 5893 , 6362 and $6438\text{\AA}$ at 25°C). In the calculation of the specific refraction by means of the formula (1), we must take for s the density at nearly the same temperature as in the measurement of n . As Slack, Reeves and Peoples' paper involves the s -values of CeCl_3 solutions at 20°C , and Mason, Hickey and Wilson's does not inform of those for PrCl_3 solutions and for the highly concentrated solutions of EuCl_3 , we use Mason's data⁽³⁾ for these solutions at 25°C . For pure water at 25°C we assume the value $s_1 = 0.99707$ given in *International Critical Tables* Vol. III. The results of calculations for molecular refraction R_2 show that the R_2 -value of CeCl_3 for $\lambda 5893\text{\AA}$ is nearly independent of the concentration C expressed in equivalents per 1000 g H_2O within the experimental errors, while those of PrCl_3 , SmCl_3 and EuCl_3 decrease slightly with increasing concentration

for all the wave-lengths used. The R_2 -value corresponding to $C=0$ i.e. in dissociated states, given in Table I, is obtained by graphical extrapolation in the $C-R_2$ curve which is a very nearly straight line for all the chlorides and for all the wave-lengths. The R_2 -values of PrCl_3 , SmCl_3 and EuCl_3 in dissociated states decrease slightly with increasing wave-lengths in the spectral region under investigation.

Table I.

R_2 -values at infinite dilution.

Salts	λ in $\text{\AA}$	CeCl_3	PrCl_3	SmCl_3	EuCl_3
	6438		30.50	29.45	29.50
	6362		30.60		29.52
	5893	31.9	(30.60)	29.50	29.56
	5461		30.70	29.65	29.90
	5086		30.60	29.70	30.15
	4811				30.22

According to Fajans⁽⁴⁾ the molecular refraction R_2 of an electrolyte in dissociated state is given by the sum of the refractions of the component ions. Thus we can determine the refraction of the rare earth ions Ce^{+++} , Pr^{+++} , Sm^{+++} and Eu^{+++} for $\lambda 5893\text{\AA}$ in aqueous solutions from the R_2 -values of their chlorides⁽⁵⁾ in infinite dilution and the value $9.06^{(6)}$ of ionic refraction of Cl^- , as shown in Table II. Roberts, Wallace and Pierce⁽⁷⁾ have determined the R_2 -values of $\text{Ce}_2(\text{SO}_4)_3$ and $\text{La}_2(\text{SO}_4)_3$ at 18°C for the wave-lengths in the range extending from $\lambda 3131\text{\AA}$ to $\lambda 5790\text{\AA}$. Hence we have the R_2 -values 51.4 and

Table II.

Ionic refractions (D -lines) in aqueous solutions.

La^{+++}	Ce^{+++}	Pr^{+++}	Sm^{+++}	Eu^{+++}
1.39(F)	3.62(R)	3.42(M)	2.32(M)	2.38(M)
2.48(R)	4.72(S)			

The letters F , R , S and M indicate that the values come out from the data given by Fajans, Roberts, Slack and Mason, respectively.

49.11 of these sulphates for $\lambda 5893 \text{ \AA}$ by graphical extrapolation, and obtain the values 3.62 and 2.48 as the ionic refractions of Ce^{+++} and La^{+++} by assuming the refraction value $14.72^{(8)}$ of SO_4^{--} , while Fajans⁽⁹⁾ has given the value 1.39 for the refraction of La^{+++} . These values are also included in Table II. The value 3.62 (*R*) seems to be more reliable than 4.72 (*S*) as the ionic refraction of Ce^{+++} , while the value 2.48 (*R*) more reliable than 1.39 (*F*) for La^{+++} if we take the experimental accuracy into account. From Table II it is found that the ions Ce^{+++} and Pr^{+++} have greater refractions than La^{+++} , Sm^{+++} and Eu^{+++} , just as is the case for the magnetic rotation which is treated in the following section.

2. FARADAY EFFECT.

The specific rotation constant $[D]$ of a substance is defined by the formula

$$[D] = \frac{n\omega\lambda^2}{s(n^2+2)^2} \quad \dots\dots\dots (3)$$

where ω is the Verdet constant (in min. per cm. gauss) for the wave-length λ (in cm.). The molecular rotation constant a_2 of a solute in aqueous solutions is computed by means of the formula

$$\frac{a_2}{M} \equiv [D_2] = \frac{1}{\tau_2} [D] - \frac{\tau_1}{\tau_2} [D_1], \quad \dots (4)$$

in which $[D]$, $[D_1]$ and $[D_2]$ are the specific rotation constants of the solution, the solvent and the solute, respectively.

Roberts, Wallace and Pierce⁽¹⁰⁾ have determined the rotation constant $[D_2]/\lambda^2$ of $\text{La}_2(\text{SO}_4)_3$ and $\text{Ce}_2(\text{SO}_4)_3$ at 22°C . for the wave-lengths extending from $\lambda 3128 \text{ \AA}$ to $\lambda 5780 \text{ \AA}$. They have investigated one dilute solution of $100\tau_2 = 2.663$ for $\text{La}_2(\text{SO}_4)_3$ and three solutions of $100\tau_2 = 10.356$, 7.242, 4.378 for $\text{Ce}_2(\text{SO}_4)_3$, and have found that the $[D_2]/\lambda^2$ -value of $\text{Ce}_2(\text{SO}_4)_3$ is nearly independent of the concentration. We therefore take it for granted that their obtained values represent as well those for nearly infinite dilution and thus obtain the molecular rotation constants of these sulphates at dissociated states, which are given in Table III. The a_2 -values for $\lambda 5893 \text{ \AA}$ are determined by graphical extrapolation from the a_2 - λ curves.

Mason, Hickey and Wilson⁽¹¹⁾ have also determined the rotation constant $[D_2]/\lambda^2$ of PrCl_3 , SmCl_3 and EuCl_3 in aqueous solutions at 25°C over the range $\lambda 4811 \sim 6438 \text{ \AA}$. Therefrom we obtain the a_2 -values of these chlorides.

Table III.
 a_2 -values of $\text{La}_2(\text{SO}_4)_3$ and $\text{Ce}_2(\text{SO}_4)_3$
(in 10^{-10} min. cm^2).

λ in $\text{\AA}$	$\text{La}_2(\text{SO}_4)_3$	$\text{Ce}_2(\text{SO}_4)_3$
5893	(-2.2)	(-103)
5780	-2.4	-104
5461	-3.1	-107
4350	-4.5	-129
4047	-6.1	-140
3652	-4.1	-164
3341	-4.5	-201
3128	-6.7	-265

Slack, Reeves and Peoples⁽¹²⁾ have measured the refractive index n ($26 \sim 30^\circ\text{C}$) and the Verdet constant ω (20°C) for the wave-length $\lambda 5893 \text{ \AA}$ of CeCl_3 solutions. Making use of these values we can compute the a_2 -values of CeCl_3 by means of the formulae (3) and (4).

The a_2 -values of CeCl_3 , SmCl_3 and EuCl_3 decrease with increasing concentration, while that of PrCl_3 is nearly independent of the concentration. The values corresponding to $C=0$ given in Table IV are obtained by graphical extrapolation in the C - a_2 curves which are nearly straight for all three electrolytes.

Table IV.
 a_2 -values of rare earth chlorides
(in 10^{-10} min. cm^2).

Salts λ in $\text{\AA}$	CeCl_3	PrCl_3	SmCl_3	EuCl_3
6438		-35.8	9.55	8.7
5893	-40	(-36.5)*	9.05	7.80
5461		-37.0	9.37	7.63
5086		-38.4	9.20	7.60
4811				7.53

* Determined by graphical interpolation in the a_2 - λ curve.

It is seen from Table III and IV that the a_2 -values of $\text{La}_2(\text{SO}_4)_3$, $\text{Ce}_2(\text{SO}_4)_3$, PrCl_3 , SmCl_3 , and EuCl_3 at infinite dilution tend to increase with increasing wave-lengths.

In previous papers⁽¹³⁾ we have found that the molecular rotation constant a_2 of an electrolyte at infinite dilution is given by the sum of the rotation constants of the component ions, and have determined the rotation constants of many ions for $\lambda 5893 \text{ \AA}$ in aqueous solutions. Using the values of the ionic rotation constants of Cl^- and SO_4^{--} given in a previous paper⁽¹⁴⁾ and the a_2 -values of the rare earth salts at dissociated states obtained above, we get the values of the

rotation constants of the rare earth ions which are shown in Table V. If these ions produce

Table V.

Ionic rotation constants (*D*-lines) in aqueous solutions.
(in 10⁻¹⁴ radian cm²).

La ⁺⁺⁺	Ce ⁺⁺⁺	Pr ⁺⁺⁺	Sm ⁺⁺⁺	Eu ⁺⁺⁺
-11.8	-154*	-140	-7.2	-10.8

* The mean of the two values obtained from CeCl₃ and Ce₂(SO₄)₃.

no hydration effect in aqueous solutions, the negative values of the rotation constants should be attributed to the paramagnetic properties of the ions. Ce⁺⁺⁺ and Pr⁺⁺⁺ have greater negative values than La⁺⁺⁺, Sm⁺⁺⁺ and Eu⁺⁺⁺, which fact corresponds to the similar relation found in the case of ionic refraction (cf. the preceding section).

In conclusion I wish to express my gratitudes to Japan Society for the Promotion of Scientific Research and to the Department of Education for financial supports.

References.

(1) F. G. Slack, R. L. Reeves and J. A. Peoples, Phys. Rev. **46** (1934), 724.
(2) C. M. Mason, J. W. Hickey and W. K. Wilson, J. Am. Chem. Soc. **62** (1940), 95.
(3) C. M. Mason kindly reported the data for the densities of aqueous solutions of EuCl₃, PrCl₃ and CeCl₃ at 25°C to the writer in a private communication.
(4) K. Fajans, Z. f. Phys. **23** (1924), 1; K. Fajans and R. Luehdemann, Z. f. phys. Chem. (B) **29** (1935), 150.
(5) The *R*₂-value of PrCl₃ for λ 5893 Å is determined by graphical interpolation from the λ-*R*₂ curve.
(6) K. Fajans and R. Luehdemann, loc. cit.
(7) R. W. Roberts, L. A. Wallace and I. T. Pierce, Phil. Mag. **17** (1934), 934.
(8) K. Fajans and R. Luehdemann, loc. cit.
(9) loc. cit.
(10) loc. cit.
(11) loc. cit.
(12) loc. cit.
(13) A. Okazaki, Mem. Ryojun Coll. Eng. **9** (1936), 101; ibid. **10** (1937), 89; ibid. **12** (1939), 45; Proc. Phys.-Math. Soc. Japan, **24** (1942), 357.
(14) A. Okazaki, Proc. Phys.-Math. Soc. Japan, **24** (1942), 357.

Statistische Forschung der
Barkhausenspruenge.

Von Harunobu SAWADA.

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(Eingegangen am Dezember 27, 1943.)

1. EINLEITUNG.

Eine statistische Forschung der Barkhausenspruenge würde auf einem Eisendraht durchgeführt. Die Zahlen und die Grossenverteilungen der Barkhausenspruenge wurden mit Verschiedenen Suchspulen gemessen. Diese Messergebnisse wurden mit einer einfachen Theorie gut erklärt. Auch die zeitliche Verteilung der Spruenge wurde gleichzeitig untergesucht.

2. MESSANORDNUNG.

Der Probedraht ist ein ausgegluehter Eisendraht mit 3% Si 100 mm lang und 2 mm dick. Die

Suchspulen wurden unmittelbar auf diesen Draht, wie in der Tabelle I gezeigt, mit der Hand gewickelt.

Table I. Suchspulen.

Spulenlänge mm	1,2	2,0	3,4	4,3	4,8	6,2	8,2
Windungszahl	500	1,000	1,500	2,000	2,500	3,000	4,000

Der Messverstaerker ist eine R-C-Koppelungs-type mit der Spannungsverstaerkung 134 db und mit dem linearen Frequenzbereich von 40 bis 30,000 Hz. Die Spruengsaufnahmen wurden durch die elektromagnetische Oszillograph mit dem Vibrator gemacht, dessen linearen Frequenzbereich von 0 bis 3,000 Hz. Andersseits wurde es

gefunden durch die Kathodenoszillographmessung mit demselben Draht, dass die Laufzeit einzelnes Sprungs kuerzer als 10^{-4} Sek. ist. Also hat der Vibrator ganz ballistischerweise ausgeschlagen und wir koennen die einzelne Aufnahme hoehe als die Groesse des entsprechenden Sprungs annehmen.

3. MESSERGEBNISSE.

Die Messungen wurden an zwei Punkte der Hystereseschleife durchgefuehrt. Die magnetische Feldstaerke und ihre Aenderungsgeschwindigkeit dabei sind in der Tabelle II gezeigt.

Tabelle II. Feldstaerke an Messpunkte.

Messpunkt.	Hauptfeld.	
	ausser. Feld,	effekt. Wert,
	Oe.	Oe.
A	0	-0,80
B	+15,9	+3,35
Zusatzfeld.		
	ausser. Feld,	Aenderungsgeschw.
	Oe.	Oe/Sek.
	-0,190	-0,00530
	+0,119	+0,00902

Je 12 Sprungsaufnahmen wurden fuer die beide Messpunkte und mit jede Suchspule aufgenommen. Jede Aufnahme enthielt von 69 bis 380 Spruenge in der Aufnahmezeit von 0,49 bis 0,63 Sek.. Die erwachtenweise gewonnene Grossenverteilungen sind in die Abb. 1 gezeigt. Abbildet

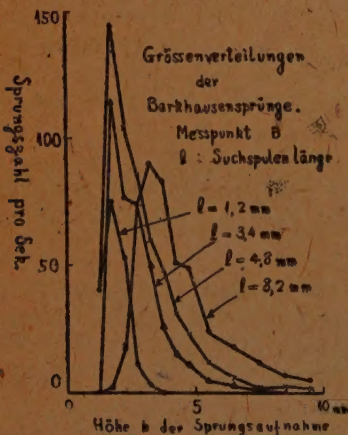


Abb. 1.

man mit diesen Ergebnissen die Zahl N_i der Spruenge, deren Grossen oberhalb jeder Untergrenze liegen, gegen die Suchspulenlaenge l , so kann man eine schoene Regelmaessigkeit finden,

wie in der Abb. 2 gezeigt. Diese Spruengszahlen N_i machen die Geradengruppe gegen die Spulenlaenge l und ihre Neigungen zur l -Achse werden kleiner mit jeder wachsenden Untergrenze und auch die Schnittpunkte l_0 jeder Gerade mit l -Achse verschieben sich nach $+l$ -Richtung.

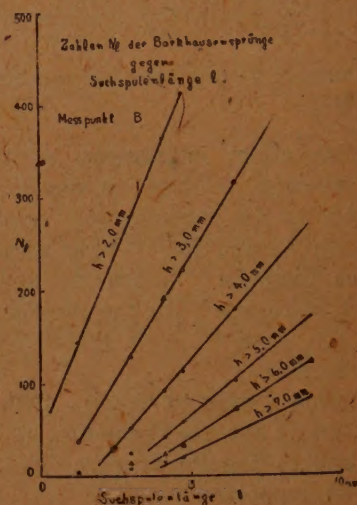


Abb. 2.

4. ERKLAERUNG.

Diese Ergebnisse kann man mit der folgenden Annahme gut erklaren. 1) Aendert die aeuessere Feldstaerke sehr langsam, entstehn dabei zwei oder mehr Spruenge niemals gleichzeitig. 2) Der Bezirk hat eine zylinderartige Form mit gleicher Schnittabmessung, doch seine Laenge p , parallel zur Drahtachse, bildet eine Verteilungsfunktion $g(p)$. 3) Die Spruengsgroesse ist proportionell zu solcher Laenge q , womit der entsprechende Bezirk in der Suchspule enthielt wurde, doch hat sie keine Beziehung zur Lage, die dieser im Draht besitzt. 4) Die Dichtigkeit m der Bezirke ist konstant im Draht ueberall, demnach ist die Zahl der umklappen Bezirke mdx , deren Zentren in Gebiete dx des Drahts liegen. 5) Wenn die Spruenge durch den Verstaerker passieren, verschwinden die kleinere wegen des Geraeusches. Daher machen nur die Umklappen in solchen Bezirken, deren in der Suchspule enthaltende Laenge q ueber eine Untergrenze s sind, d. h. $q > s$, die klaren Sprungsaufnahmen. Als die Verteilungsfunktion $g(p)$ wurden zwei folgend gewählt.

$$g_1(p)dp = 1/r \exp(-p/r)dp, \quad \bar{p} = r \quad (1)$$

$$g_2(p)dp = p/r^2 \exp(-p/r)dp, \quad \bar{p} = 2r \quad (1')$$

Dann wird die Zahl N_i der in der Suchspule

mm lang entstehenden Spruenge mit $g_1(p)$ oder $g_2(p)$ durch die naechsten Formeln gegeben.

$$(N_1)_1 = m \exp(-s/r)(r+l-s) \quad (2)$$

$$(N_1)_2 = m \exp(-s/r) \{2r+s+(l-s)(s/r+1)\} \quad (2)$$

Oder mit der folgenden Abkuerzung,

$$s/r = x \quad (3), \quad N_1 = n(l-l_0) \quad (4)$$

werden die Formeln

$$\left. \begin{aligned} n_1 &= m \exp(-x) \\ (l_0)_1 &= r(x+1) \end{aligned} \right\} \quad (5)$$

$$\left. \begin{aligned} n_2 &= m \exp(-x) \cdot (x+1) \\ (l_0)_2 &= r(x^2-2)/(x+1) \end{aligned} \right\} \quad (5)$$

gewonnen. Diese Formeln erklaren gut die Ergebnisse, die Abb. 2, nach $g_1(p)$ sowie nach $g_2(p)$ mit die folgenden Parameterwerten, wie in der Tabelle III gezeigt.

Tabelle. III.

Verteilungsfh.	Messpunkt A			Messpunkt B		
	d	r mm	p mm	d	r mm	p mm
$g_1(p)$	367	1,85	1,85	302	2,70	2,70
$g_2(p)$	230	1,12	2,24	189	1,55	3,10

Aber, dass jede Groessenverteilung immer eine Maximum besitzt, erklart sich nur aus $g_2(p)$. Deshalb unterstuetzt die Messergebnisse $g_2(p)$ als die Verteilungsfunktion der Bezirkslaenge p .

5. MAGNETISCHER BEZIRK UND INNERENSCHNUNG.

Die Bezirksgroessenverteilung werde allgemein durch die Innerenspannung entschieden. Aber wir koennen nicht einfach schliessen die Ueber-einstimmung der beiden Verteilungen, weil der Umklappenvorgang noch nicht ganz klar ist. Doch wenn wir es annehmen, dass das Umklappen von einem Bezirksende nach anders lauft, oder, dass ein Keim irgendwo innerhalb des Bezirks entsteht und das Umklappen gleichzeitig nach die beiden Enden lauft, so werden diese Verteilungen ganz ubereinstimmt. Fuer diese beiden Faelle wir die Ursache der Innerenspannungsverteilung $g_2(p)$ folgenderweise vermuten. Weil jedes Innerenspannungsmaximum irgendeine Konzentriertstelle ist, also hat es eine solche Neigung, dass es gegeneinander etwas trennen-bleibt. Durch die Wahrscheinlichkeitsrechnung dieser Vermutung kann man die Funktion $g_2(p)$ als Entfernungsverteilung der Innerenspannungs-maxima formeln.

6. ZEITLICHE VERTEILUNG DER BARKHAUSENSPRUENGE.

Die zeitliche Verteilung der Spruenge wurde auch gemessen. Ein Beispiel der Ergebnisse ist in der Abb. 3 mit der theoretischen Kurve gezeigt. Diese Theorie ist ganz aehnlich jener zur Innerenspannungsverteilung und ihre Funktionform ist dieselbe mit $g_2(p)$. In der Menge der umklappenden Bezirke hat jeder durch die vielen Ursachen die zu ihrem Zustand entsprechende Energie Ei . Wenn ein Bezirk irgendwo innerhalb des Drahts umgeklappt hat, dann waechst Ei des am naechsten zu umklappen geordnetes Bezirks mit einer Zunahme αt durch die lineare Veraenderung der ausseren Feldstaerke. Schliesslich erreicht Ei einem Grenzwert und dieser Bezirk umklappt ploetzlich. Naemlich wird die relative Wahrscheinlichkeit $f(t)$ des Umklappens in der form αt geschrieben. Einerseits ist die Laufzeit einzelnes Spruengs sehr kurz, also ist das ganze Messungszeitintervall gleich die Summe der Spruengspausen. Mit dieser Begrenzung kommt $f(t)$ zu folgende Form.

$$f(t)dt = t/\alpha^2 \exp(-t/\alpha)dt, \quad \bar{t} = 2\alpha \quad (6)$$

Diese theoretischen Kurven einstimmen gut mit der Messergebnisse, wie in der Abb. 3 gezeigt.

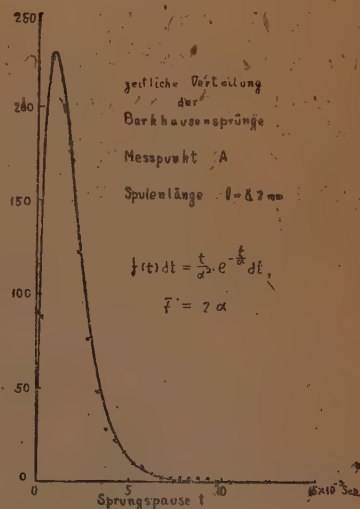


Abb. 3.

Band-spectral Intensity Distributions in Electrodeless Ring Discharge of Ultra-short Wave. II. Study on OH Band.

By Tadao HORIE.

Faculty of Science, Osaka Imperial University.

(Received December 27, 1943.)

1. INTRODUCTION.

The spectrum of the OH molecule shows a distribution of rotational energy representing thermal equilibrium as expected when it is excited in flame and arc, but exhibits an abnormal distribution in the other types of excitations.⁽¹⁾ The emission spectrum of the OH molecule excited in an electric discharge shows an energy distribution greatly in excess of the thermal energy of the emitting gas. It has been stated by many authors⁽²⁾ that such an OH band-spectrum arises from the simultaneous dissociation of H_2O and excitation of OH by electric impact. A further key to the explanation of the mechanism of the simultaneous dissociation and excitation process might be found in a study of the spectrum excited under more simple conditions.

In the previous papers⁽³⁾, it has been reported that, in the electrodeless ring discharge, the rotational temperatures derived from CO and N_2 band-spectra are quite close to the true temperature of the gas in which the molecules are excited. The following investigation is a study of the rotational energy distribution of the OH molecule by measurements of the $(0, 0)$ 3064 Å band of $^2\Sigma \rightarrow ^2\Pi$ system excited under the same conditions of discharge as before.

2. EXPERIMENTAL AND RESULTS.

The continuous flow of water vapour through the discharge tube was maintained at the pressure 0.08 mm Hg during exposure. The temperature of the gas was 600°K. The photograms were taken in the first order (dispersion 2.4 Å/mm) of a 21-foot concave grating. The positive crator of a carbon arc was used for cor-

J''	P_1	Q_1	P_2	Q_2
$1\frac{1}{2}$	— b	411 a'	— b	— b
$2\frac{1}{2}$	550 s	540 a'	— b	— b
$3\frac{1}{2}$	— b	690 a'	550 i	— b
$4\frac{1}{2}$	— b	635 i	580 s	— b
$5\frac{1}{2}$	542 i	631 s	— b	580 i''
$6\frac{1}{2}$	487 i'	600 s	425 s	538 i'
$7\frac{1}{2}$	— b	— b	— b	446 i''
$8\frac{1}{2}$	— b	490 i''	409 i'	— b
$9\frac{1}{2}$	378 s	445 i'	377 a	— b
$10\frac{1}{2}$	300 i''	429 i'	359 s	348 i''
$11\frac{1}{2}$	300 i''	— b	338 i''	346 s
$12\frac{1}{2}$	305 i'	323 i''	307 a	334 s
$13\frac{1}{2}$	271 s	331 a	253 s	— b
$14\frac{1}{2}$	248 s	316 s	272 i'	— b
$15\frac{1}{2}$	221 s	294 s	235 i'	309 i'
$16\frac{1}{2}$	220 i'	279 a	230 a	274 s
$17\frac{1}{2}$	196 i	260 i''	— b	279 i
$18\frac{1}{2}$	200 i'	260 i''	212 s	310 s
$19\frac{1}{2}$	197 i'	259 i'	216 a	270 a'
$20\frac{1}{2}$	193 i	285 a	189 s	281 i'
$21\frac{1}{2}$	191 s	288 i'	179 s	256 s
$22\frac{1}{2}$	179 s	274 a'	182 s	275 i'
$23\frac{1}{2}$	155 s	294 a	130 s	199 i'
$24\frac{1}{2}$	121 s	275 a	118 s	175 i'
$25\frac{1}{2}$	101 s	134 s	69 s	118 i''
$26\frac{1}{2}$	60 s	63 i'	45 s	—
$27\frac{1}{2}$	28 s	—	—	—

The significance of the symbols employed in the above table is as follows.

- s: separated discretely and symmetrical.
- a: slightly asymmetrical due to superposition of a weak line.
- a': asymmetrical due to superposition of a somewhat strong line.
- i: interfered with a neighbouring line at their tails.
- i': interfered up to about half the height with a neighbour.
- i'': interferences are too close to be analysed discretely.
- b: blended completely.

recting the variations of the sensitivity of the photographic plates with wave-length⁽⁴⁾. The method of photographing was described in the previous publication⁽⁵⁾.

According to the microphotometric figures, some lines are superposed entirely with each other, some superposed partially and some separated discretely. Then the intensities of lines can not be read directly from the peaks of the figure. The microphotometer records were reduced to the figures drawn in intensity scale and partially superposed lines were analysed into each other and the corresponding area of each line form was employed as intensity measurement.

The lines of (0,0) band were identified from data of Fortrat⁽⁶⁾ in reference with the paper of Mulliken⁽⁷⁾. The result of measurements is tabulated as above.

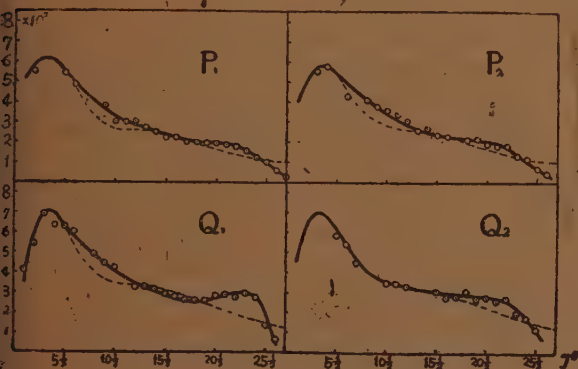


Fig. 1. Relative intensity distributions.

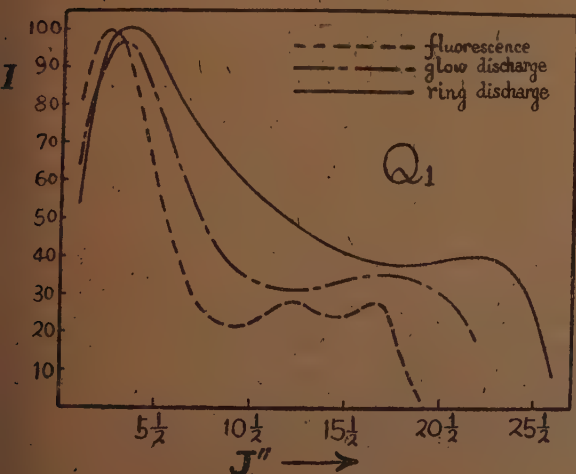


Fig. 2. Comparison with other results.

The measured relative intensities of the lines of the four principal branches are plotted against the corresponding rotational quantum numbers, J'' , in Fig. 1.

In Fig. 2 the intensity distribution curve for the Q_1 branch is compared with the results obtained by Lyman (loc. cit.) under the other types of excitation conditions.

3. DISCUSSION.

As mentioned in the introduction, the rotational intensity distributions of Boltzmann type have been shown in the case of some diatomic molecular gases. The non-Boltzmann distribution obtained may be supposed to indicate the abnormality in the distribution of the rotational states of OH^* produced in the process $H_2O \rightarrow OH^* + H$.

If we assume that the molecular group in the rotational state corresponding to 600°K and the other to 8,000°K are mixed in the abundance ratio 6:1 and no equilibrium exists between both at all, then the theoretical intensity distributions may be such as shown with broken curves in Fig. 1.

The deviation which occurs around $J'' = 25 \frac{1}{2}$ is particularly essential. The experimental curve falls down steeply. It may be lucid that such a characteristic behaviour cannot be explained by any assumption based on a Boltzmann distribution as above, and at the same time supply a key to reveal the dissociation mechanism of H_2O .

4. SUMMARIES.

The (0,0) band of the OH molecule excited in an electrodeless ring discharge was photographed in the first order of a 21-foot concave grating. The intensity distributions of P_1 , Q_1 , P_2 and Q_2 branches were studied, the intensities of lines being read from the areas instead of the peaks.

Every branch shows the rotational distribution of the same characteristic behaviours. Each of the measured relative intensity distributions represents a remarkable deviation around $J'' = 25 \frac{1}{2}$ from the graph of the theoretical intensity distribution of the gas in which a temperature inhomogeneity of 600°K and 8000°K exists in the ratio 6:1 in amount.

In conclusion the author wishes to express his gratitude to Professor T. Tanaka for his interest and encouragements during the course of this work.

References

- (1) E. R. Lyman, *Phys. Rev.*, **53** (1938), 379; **56** (1939), 466.
- (2) K. F. Bonhoeffer and T. G. Pearson, *ZS. f. Phys. Chem.*, **14** (1931); I. O. Oldenberg, *Phys. Rev.*, **46** (1934), 210; H. Wakesima, *Proc. Phys.-Math. Soc. Japan*, **24** (1942), 367.
- (3) T. Horie, *Proc. Phys.-Math. Soc. Japan*, **22** (1940), 787; **25** (1943), 595.
- (4) "Temperature", *Am. Inst. of Phys.*, (1941), 1141.
- (5) T. Horie, *Proc. Phys.-Math. Soc. Japan*, **24** (1942), 172.
- (6) M. R. Fortrat, *Jour. d. Phys.*, **5** (1924), 20.
- (7) R. S. Mulliken, *Phys. Rev.*, **32** (1928), 388.

On the Evaporation of Oxide Cathode.

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(Received February 29, 1944.)

As well known, the active centres of the oxide cathode are due to the existence of excess atoms. Therefore, it can be expected that the rate of evaporation of oxide cathode is affected by its thermionic activity, if these excess barium atoms evaporate for the most part. Against these expectation, however, we found that the rate of evaporation does not change with the thermionic emission, but it is influenced by the secondary structure of the crystal.

1. EXPERIMENTAL METHOD.

The rate of evaporation of Ba was measured by the rate of increase of the thermionic emission from tungsten wire on which Ba atoms deposit. The construction of the bulb is shown in Fig. 1. For the cathode and heater, the parts of UY-56A were employed, and the solid solution of BaCO_3 and SrCO_3 was coated about 10 mm length on the middle part of the cathode sleeve where the temperature is fairly uniform. The cylindrical nickel anode, 15 mm length and 6 mm diameter was mounted surrounding the cathode, so as to be able to slide up and down. Outside of this anode, tungsten wire of hair pin type, 0.15 mm dia, 40 mm total length, was stretched. After the bulb was evacuated about one hour at 300°C, the anode was baked by high frequency furnace, and the carbonate of cathode was decomposed. Finally, the bulb was tipped off.

The experimental procedure was as follows: The tungsten filament was heated at about 600°C~700°C, after the flashing at 2000°K. The oxide cathode was heated at desired temperature,

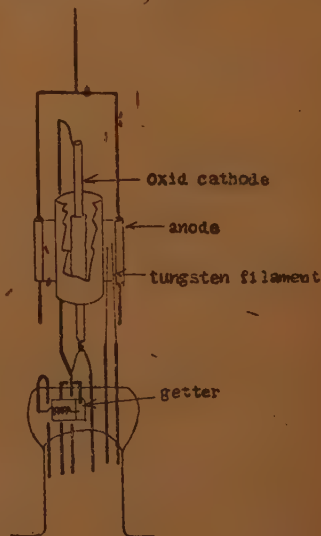


Fig. 1.

and then the anode was slide away so as to expose the tungsten filament in the molecular beam of Ba or BaO from the oxide cathode. After few minutes, anode was slide down to separate the cathode and filament. Then the thermionic emission from filament to anode was measured by the galvanometer (10^{-10} amp/mm). Repeating these process, we obtained the curve

shown in Fig. 2. The thermionic emission from the tungsten filament reaches the maximum value when the monomolecular layer of Ba or BaO is completed, and then it decreases slightly. The heat of evaporation can be determined by these experiments, varying the temperature of the cathode.

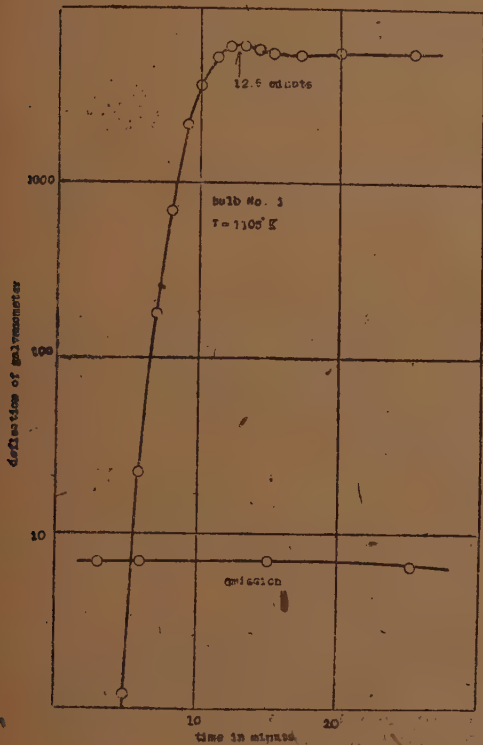


Fig. 2.

2. EXPERIMENTAL RESULTS AND DISCUSSION.

The results are shown in Fig. 3 and Table I. We can see that the rates of evaporation do not differ more than few times, in spite of the variation of the thermionic emission of about 40 times. In order to confirm these relation, we measured the rate of evaporation, drifting the anode current through the layer of the oxide. The excess barium ions will be drifted toward the inside of the oxide layer by the electric field due to this anode current. And consequently the surface density of the active centres will decrease.⁽¹⁾ Hence, if the excess barium atoms

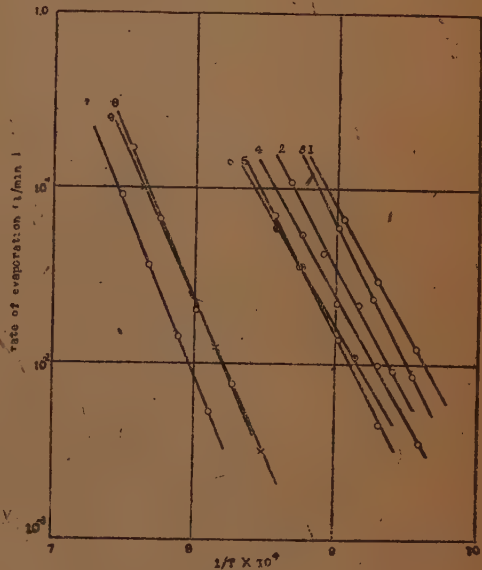


Fig. 3.

Table 1.

structure	substance	No.	evap.(eV) heat of	rate of evap. (1110°K)	emission (1000°K)	core metal
not sintered	BaSrO ₂ solid solution	1	2.95	7.8×10^{-2} 1/min	40 ma	electrolytic nickel
		2	2.95	3.5×10^{-2}	100	
		3	3.1	8.4×10^{-2}	250	
		4	2.8	2.4×10^{-2}	90	
		5	3.05	1.5×10^{-2}	60	
		6	2.75	1.4×10^{-3}	1600	containing magnesium
		mean	2.9			
sintered	BaO	7	3.95	1.1×10^{-4}	0.13	electrolytic nickel
		8	3.85	3.5×10^{-4}		
		mean	3.9			
	BaSrO ₂ solid solution	9	3.7	4.3×10^{-4}	1.5	

evaporate for the most part, the rate of evaporation should be decreased remarkably. But, as the results, we found that it suffers no change, in spite of the variation of the thermionic emission, as shown in the next table.

anode current	emission (670°K)	rate of evap. (1110°K)
0 mA	1.35 mA	2.7×10^{-2} 1/min
15	0.40	2.7
20	0.25	2.9

According to these results, we must conclude that the excess barium atoms do not evaporate for the most part, even if the activity of oxide is very high. The Ba atom alone, also, can not evaporate from the lattice point of the crystal, because the heat of dissociation of BaO (10.3eV) is far greater than this heat of evaporation (2.9eV). Therefore we must interpret that these phenomena are the sublimation of BaO molecule from the oxide crystal. However, the heat of sublimation we obtained (2.9eV) is far smaller than the value obtained by A. Claassen and C. F. Veenemans (3.9eV)⁽²⁾ or J. Blewett and others (3.8eV).⁽³⁾ We employed the 50 % solid solution of BaO and SrO which is not sintered, (fine grain) having high activity, while their samples were BaO alone which probably were sintered, (coarse grain) for BaO alone is very easily sintered when it is prepared from carbonate or hydroxide by decomposition. Therefore, we repeated the same experiment with the sintered sample of BaO alone which is prepared from carbonate by decomposition. The results are shown in Fig. 3 and Table. I. The heat of sublimation agree with those obtained by them and is smaller than that of sintered by about 1.0eV. This difference will probably due to the secondary structure of the crystal such as grain size, incompleteness of lattice, etc.

The rate of evaporation can be expressed approximately by $M = A \exp(-Ee/kT)$. A and E determined from our experiment are shown in the next table. The data due to J. Blewett are also shown.

	A (gr/cm ² sec)	E (eV)
BaSrO ₂ (not sintered)	3.3×10^6	2.9
BaO (sintered)	2.7×10^6	3.9
BaO (Blewett)	3.6×10^6	3.8

The absolute values of the rate of evaporation were determined under the assumption that the BaO crystal which is deposited on the tungsten surface arranges so as to be the (111) plane parallel with the surface of tungsten, and that

the thermoionic emission becomes maximum when the monomolecular layer of such film is completed.

3. THE STABILITY OF THE CRYSTAL AND THE THERMIONIC ACTIVITY.

It was suggested that, if the oxide cathode is sintered by the wrong treatment, its thermionic emission becomes very poor.⁽⁴⁾ Above results seems to tell us that the rate of evaporation is related with such a secondary structure of the crystal.

When the core metal of the oxide cathode contains no reducing elements such as Mg, Al, Mn, or Si, the activity of the cathode is obtained only by the thermal decomposition of the oxide.⁽⁴⁾ In this case the active centres may be produced, by the evaporation of oxygen atom which becomes oxygen molecule in the gas phase. The excess Ba atom remained is trapped interstitially between lattice points. Let the energy required for this process be ϵ the change of free energy is given by

$$-\frac{kT}{2} \left[\log \left(\frac{2\pi mkT}{h^2} \right)^{3/2} + \log \frac{V}{\nu} \right] + kT \log \frac{n}{N-n} \quad (1)$$

where n and ν is the concentration of the excess barium atoms and oxygen molecules respectively, N is the allowed number of the excess barium atoms in the lattice. From the condition of equilibrium, the expression (1) must vanish, that is,

$$\frac{n}{N} = \left(\frac{\nu}{V} \right)^{-1/2} \left(\frac{2\pi mkT}{h^2} \right)^{3/4} \exp -\epsilon/kT \quad (2)$$

As ν is proportional to the pressure p of the oxygen gas, we can obtain the relation $n \sim p^{-1/2}$, which we verified with the recent experiment.⁽⁴⁾

As the heat of dissociation of oxide is the sum of the heat of sublimation of oxide and the heat of dissociation of oxide molecule, we can conclude from above results that the heat of dissociation of the oxide not sintered is less than that of sintered by about 1.0eV. Therefore the energy ϵ of not sintered will be also less than that of sintered by about 1.0eV. Hence under the same condition the density of excess barium of not sintered oxide is more than that of sintered by about $\exp(1.0e/kT)$ times, that is, 10^5 times at 1100°K. We can, therefore, understand that the origin of the high activity

of the not sintered oxide is lie in the less stable-ness of such oxide.

References.

(1) H. Kawamura, A. Shinohara, Mazda Kenkyujiho (in Japanese) 17 (1942), 453.

(2) A. Claassen, C. F. Veenemans, ZS. f. Phys. 80 (1933), 342.

(3) J. Blewett, and others, Jour. Chem. Phys. 7 (1939), 478.

(4) H. Kawamura, Jour. Phys.-Math. Soc. Japan (in Japanese), 17 (1943), 159.

Note on the Scattering of Neutrons by ${}^4\text{He}$.

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(Received April 14, 1944.)

1. In the previous paper,⁽¹⁾ the author has investigated the potential scattering of neutrons by ${}^4\text{He}$. The discussions have there been limited to the scattering of S-neutron waves, for which the phase shifts and the partial cross sections have been computed for the neutron's energy of 0.039 EV, 1 MEV and 2.5 MEV. Those calculations were based upon the Hartree-Fock's equation for the colliding neutrons, and the target nucleus ${}^4\text{He}$ was described by the oscillator model, the possibility of its distortion during the collision being entirely disregarded. The computed value of the cross section for thermal neutrons was found to be consistent with the experimental data. With regard to the P-neutrons, on the other hand, resonance scattering is known⁽²⁾ to take place at about 1 MEV of the neutron's energy. In fact, following Bohr's general theory of nuclear collisions, F. Bloch⁽³⁾ has been able to ascribe this resonance to the existence of the virtual P-doublet states in the compound-nucleus ${}^5\text{He}$. In this connection, it becomes of interest to see, whether or not the Hartree-Fock's method, such as has been employed in the previous paper, can, like the dispersion theory, give some account of the resonance scattering of the P-waves. This point is examined in the present paper. The methods of calculations are just the same as that for the scattering of S-waves, so the results only shall be reported here.

Fig. 1 shows the variation of the phase shift δ_1 of the P-neutron waves with the neutron's energy. The partial cross section Q_1 can then be evaluated by the formula

$$Q_1 = \frac{4\pi}{k^2} \sin^2 \delta_1,$$

in which $k = \sqrt{32/25 \sqrt{4\pi^2 M E_0 / h^2}}$, h is the Planck's constant, M is the neutron's mass and E_0 is the neutrons energy referred to the labo-

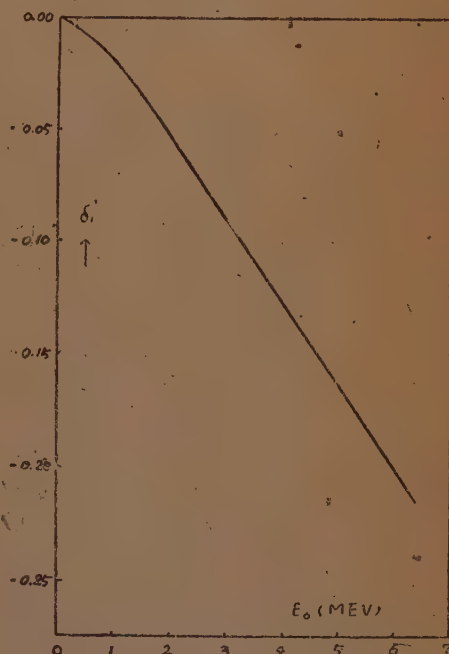


Fig. 1.

ratory coordinate system. The behaviour of Q_1 is shown in Fig. 2. We notice that our computations give no trace of the resonance phenomena mentioned above. This failure of the

theory may be understood as follows: the work of S. Watanabe⁽⁴⁾ on the binding energy of ${}^6\text{He}$,

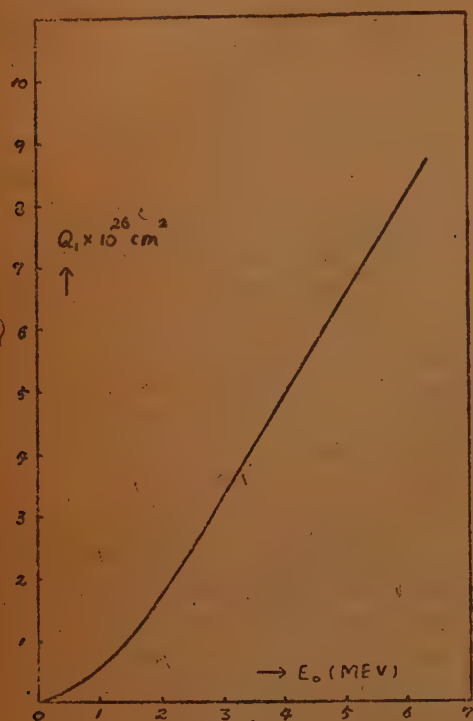


Fig. 2.

for example, shows that the first approximation of the Hartree-Fock's method yields only a very poor result as regard to the interaction of the P-neutron within the ${}^6\text{He}$ nucleus with the ${}^4\text{He}$ core, and that the higher approximations give by no means negligible contributions. It becomes then natural to conclude, that in our problem of the resonance scattering also, if we are to follow the method of Hartree-Fock, the higher approximations should not be disregarded as has been done in the present work. In fact, the

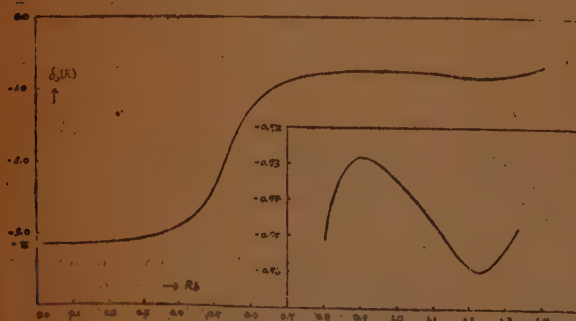


Fig. 3. $\delta_0(R)$ for $E_0=2.5$ MEV. b^{-1} is the range of nuclear forces. The additional figure shows the occurrence of extrema in magnification.

method of the compound nucleus, which proves to be successful in the theory of nuclear collisions, may, in some respect, be regarded as a phenomenological way of taking account of the violent distortions induced in the target nucleus during the collision.

2. In the course of the present computations, it is found that some errors have been committed in the paper 1, which we should like to correct in this occasion. The discontinuous curve of $\delta_0(R)$, shown in Fig. 1 of the previous paper is found to be erroneous, and must be corrected as in Fig. 3. The correct curve is continuous and $\delta_0(R)$ tends to $-\pi$ when R vanishes. The phase constant $n\pi$ (n is integers or zero) which can be arbitrarily added to δ_0 is here chosen so that δ_0 vanishes with the neutron's energy. Other normalizations are of course possible without influencing the physical results. Moreover, as is shown in Fig. 3, the corrected curve has a new minimum situating to the right of the previously found maximum point. Along the line of thought as explained in paper 1, we must then choose the mean value of $\delta_0(R)$ corresponding to these two extrema as the correct phase shift value, which situation makes the values of the phase shifts and cross sections reported in paper 1 a little too small in their absolute values. Thus, in Table I, the values completely recalculated are tabulated and compared with the previous ones.

Table I.

E_0	δ_0		$Q_0 \cdot 10^{24} \text{ cm}^2$	
	Paper 1	Recalculated	Paper 1	Recalculated
2.5 MEV	-0.73	-0.74	0.72	0.74
1.0 MEV	-0.47	-0.48	0.82	0.86
0.039 EV	-0.93 $\cdot 10^{-4}$	-0.96 $\cdot 10^{-4}$	0.90	0.95

The corrections enter only in the second places of decimals, but the figures in these places are already somewhat uncertain and may not correspond to any physical realities. All physical consequences of paper 1, accordingly, are found to be unaffected by these corrections.

References.

- (1) M. Nogami, Proc. Phys. Math. Soc. of Jap. 24 (1942), 26, (referred as paper 1).
- (2) H. Staub and H. Tatel, Phys. Rev., 58 (1940), 82p.
- (3) F. Bloch, Phys. Rev., 58 (1940), 82g.
- (4) S. Watanabe, ZS. f. Phys. 112 (1939), 159.

Vapour Pressure of the Caesium-Oxide Photocathode.

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The caesium-oxide photocathode is usually made by treating the oxidized silver surface in the caesium vapour. It is believed that the cathode thus obtained consists of the layer of Cs_2O with stoichiometric excess caesium and the colloidal particles of silver reduced by caesium. In this paper, we describe the vapour pressure, the photoelectric emission and the thermionic emission of these photocathodes.

PART I. VAPOUR PRESSURE (DYNAMICAL).

EXPERIMENTS.

The experimental tube was made of pyrex glass. (Fig. 1).

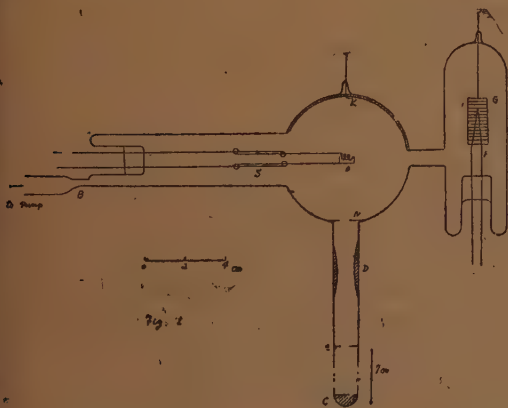


Fig. 1. Experimental Tube.

After evacuation and baking at about 500°C , silver was evaporated from tungsten coil *A* on to the bulb wall. (shaded part) The silver surface was oxidized by discharge through *K* and *L* under the pressure of oxygen gas of about 1 mmHg, which was introduced through the evacuating system. This surface becomes to now deep yellow colour after oxidation. It was calculated by the decrease of the pressure of oxygen after discharge, that the thickness of this silver oxide was 40-50 lattice layers.

After evacuating oxygen gas, metallic caesium was produced by thermit reaction of Cs_2CrO_4 and *Al* mixed powder, which was then distilled into *C*. The bulb was then sealed off at *B* and brought into a thermostat kept at 145°C (at this stage, *A* was slid to left by the device of *S*). The caesium vapour begins to effuse through a hole of diameter 0.4-0.5mm bored in a platinum plate, and reduce the silver oxide: thus the layer of the photo-sensitive caesium-oxide is formed on the silver base. *N* is a nickel plate with a hole of diameter 3mm, which is used to obtain the uniform ray of Cs atoms. We measured the photo-electric emission from this surface irradiated by a 40W tungsten lamp and the thermionic emission at 145°C and the vapour pressure during these reaction process. The vapour pressure was measured by Langmuir's positive ion method. Every Cs atom which impinges on the hot filament of tungsten is ionized and collected by *G* maintained at about -50 — -200V . Thus by measuring the ion current, we can know the number of Cs atom which impinges on the surface of tungsten filament, and consequently the vapour pressure of Cs.

2. RESULTS.

The results obtained are shown in Fig 2, in which we take the atomic ratio Cs/O in the layer, as the abscissa. The number of O atoms absorbed by silver was calculated from the decrease of the pressure of oxygen measured by a McLeod gauge. On the other hand, the number of Cs atoms which had effused in *t* sec., was calculated by the formula.

$$N = \frac{Pst}{0.75 \times 10^{-3} \times \sqrt{2\pi m k T}}$$

where *P* is the vapour pressure⁽¹⁾ of metallic Cs at *T*°K in mmHg, *S* the area of the hole *E* in cm^2 , *m* the mass of Cs atom, *k* Boltzmann's constant. As shown in Fig. 2, the photoelectric emission and the thermionic emission show the

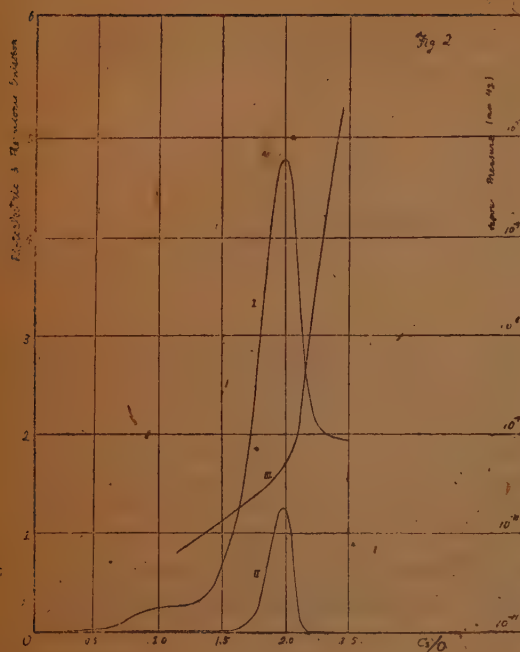


Fig. 2. Curve I. Photo-electric Emission.
Curve II. Thermionic Emission.
Curve III. Vapour Pressure.

sharp maxima at nearly $Cs/O=2$ in every experimental series⁽²⁾ and the vapour pressure shows a marked kink at this point. Such a sudden increase of the vapour pressure at point $Cs/O=2$, suggests that the phase of the caesium oxide changes decidedly, at this atomic ratio. That is, the layer does not consist of the mixture of the suboxides and the peroxides of Cs, but of the uniform compound Cs_2O . If we stop the effusion of Cs by cooling the Cs source C (Fig. 1) with ice or liquid air at any point in the range where $Cs/O > 2$, the photoelectric emission and the thermionic emission recover to a nearly same value at $Cs/O=2$, and the vapour pressure decreases by a factor 10^2 to 10^3 . These are the equilibrium values of the Cs_2O -Cs layer at this atomic ratio. (detailed in the next chapter) From these results one can conclude that the decrease of the photoelectric and thermionic emission and the sudden increase of the vapour pressure at $Cs/O=2$ are due to the deposition of metallic Cs on the surface of Cs_2O .

When one stops the effusion of Cs, this Cs film diffuses into the Cs_2O layer and a uniform layer can be obtained. On the other hand in the range $Cs/O < 2$ the Cs atom which have effused into the bulb is oxidized so rapid that the vapour pressure is very low.

As regard to the chemical reaction in the range of these atomic ratios, we may prefer the mechanism, that the oxygen atoms (or ions) liberated from Ag_2O at the interface of Ag_2O and Cs_2O diffuse through the layer of caesium oxide outwards and react with the Cs atom which have deposited on the surface. Therefore when all the Ag_2O molecules are reduced, that is when $Cs/O=2$, the reaction proceeds no more and consequently the vapour pressure of Cs increases suddenly at this point. If this mechanism is correct, the reduced Ag atom will lie in the bottom of the layer of Cs_2O not within the layer.

PART II, VAPOUR PRESSURE (EQUILIBRIUM).

1. EXPERIMENTAL.

In order to obtain the equilibrium values of the photoelectric emission, the thermionic emission and the vapour pressure at the various ratio Cs/O , the Cs source was sealed off at D, (Fig. 1) when the ratio became desired values, and the heat treatment of the tube was continued for two or three hours, until an equilibrium was attained. Then photoelectric emission etc. were measured at several temperatures between $145^\circ C$ and $100^\circ C$.

If we plot the logarithm of the vapour pressure and the thermionic emission, as the function of $1/T$, we will obtain the straight line, from which inclination we can find the heat of evaporation and the thermionic work function.

Then the tube was taken out from the thermostat, and the photoelectric emission per one Lumen of white light and the spectral distribution of the photoelectric emission were measured at room temperatures. The tube was again brought into the thermostat kept at $100^\circ C$, and silver was evaporated from A (Fig. 1) and condensed upon the surface of the Cs_2O layer.

This operation is known as the silver-activation of the photocathode. The photoelectric emission increases by several times as silver is condensed. The optimum thickness of the condensed silver is known to be about $80 \text{ \AA}$.⁽³⁾

After the heat treatment for about an hour the photoelectric emission, the thermionic emission and the vapour pressure were measured. Then bringing out the tube again, the photoelectric emission per Lumen and the spectral distribution were observed. The results of these experiments are summarised in Tab. I.

Table I.

	Ca/O	1.76	2.13	2.37	2.61	2.92	3.18
Before Silver Activation	Equilibrium Vapour Press. at 145°C (in mmHg)	$<4.5 \times 10^{-14}$	1.8×10^{-10}	3.6×10^{-9}	2.1×10^{-8}	7.0×10^{-8}	8.6×10^{-7}
	Heat of Evaporation (in eV)	—	0.76	0.83	0.90	0.94	1.02
	Photoelectric Emission at room temp. (in $\mu\text{A}/\text{Lumen}$)	7.3	11.4	12.1	12.6	7.0	12
	Selective Max. (in eV)	2.0	2.05	2.1	2.0	2.1	1.8
	Half Sensitivity Frequency (in eV)	1.7	1.55	1.5	1.55	1.65	1.4
	Threshold Frequency (in eV)	1.3	1.03	0.93	0.94	0.92	1.11
	Thermionic Emission at 120°C (in Amp/cm^2)	5.5×10^{-10}	4.5×10^{-7}	6.6×10^{-7}	5.5×10^{-7}	3.8×10^{-7}	3.7×10^{-9}
	Thermionic Work Function (in eV)	—	0.60	0.79	0.83	0.93	—
After Silver Activation	Photoelectric Emission (in $\mu\text{A}/\text{Lumen}$)	12.3	31	22	25	19	15
	Selective Max. (in eV)	2.0	1.65	1.5	1.55	1.6	1.65
	Half Sensitivity Frequency (in eV)	1.75	1.3	1.25	1.3	1.35	1.45
	Threshold Frequency (in eV)	1.5	1.07	1.08	1.12	1.13	1.29
	Thermionic Emission at 120°C (in Amp/cm^2)	1.7×10^{-11}	6.6×10^{-8}	1.4×10^{-8}	1.1×10^{-8}	—	—

2. DISCUSSION.

As shown in Tab. I, the heat of evaporation is somewhat higher than for the metallic Cs (0.75 eV)⁽⁴⁾ and increases with the ratio Cs/O. This fact suggests that the stoichiometric excess Cs atoms in Cs₂O are dispersed not as colloidal particles but atomically. If Cs were dispersed as colloidal particles, the heat of evaporation should decrease with increasing of Cs/O.

The results of the spectral distribution of the photoelectric emission are also shown in Tab. I, where we tabulated the quantum energy, with which the selective maximum happens (row 5), and also the quantum energy where the sensitivity decreases to a half of the selective maximum (row 6), and finally the threshold quantum energy (row 7). The threshold before the silver activation was determined as follows: if we take the square root of the sensitivity as the ordinate and the quantum energy as the abscissa, the observed points lie on a fairly straight line. Extrapolating this line, we can obtain the threshold.⁽⁵⁾ The threshold after the activation was determined by Fowler's method.

As shown in row 5, 6 and 7 of Tab. 1, the form of the spectral sensitivity does not vary in range where $2 < \text{Cs/O} < 3$. The absolute yield of the photoelectric emission and the thermionic emission also remain nearly at the same values in this range. In these respects, we must consider that only a little portion of the excess Cs serve as the center of electron emission. Therefore, it may be considered that the greater part of the excess Cs would exist as the suboxide.

3. THE STATE OF THE EXCESS CS.

In order to test, whether the equilibrium vapour pressure was truly due to the Cs atoms or not, we tried the following experiment. In the foregoing measurements of the vapour pressure, we fixed the filament current of the pressure gauge at 0.6 A. (or the filament temperature $T_F = 1440^\circ\text{K}$) But on varying T_F , we obtained the deflection of the galvanometer as shown in Fig. 3. (curve 1). ($P = 4.23 \times 10^{-10}$ mmHg. $T = 100^\circ\text{C}$) A curve obtained by Langmuir for the metallic Cs ($P = 6 \times 10^{-10}$ mmHg. $T = -34.5^\circ\text{C}$) is shown also in Fig. 3. (curve 2) for comparison. From these curves, we can see that the vapour pressure is surely due to the Cs atoms, at least for the range Cs/O < 2.6. As shown in these

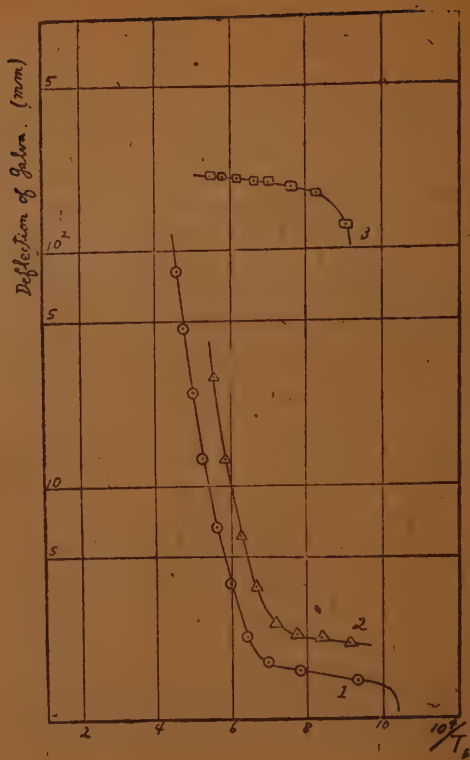


Fig. 3. Curve 1 Cs/O=2.37.
Curve 2 Cs(Langmuir).
Curve 3 Cs(Langmuir).
Curve 3 was shifted vertically by
arbitrarily amounts.

curves, no ion current is observed at lower T_F than about 1000°K , where the ion current begins to flow suddenly, thereafter it increases gradually, because of the increase of the effective length of the filament. At about $T_F = 1540^\circ\text{K}$ it begins to increase exponentially, which is due to the photoelectric emission from the ion collector G under the influence of the filament radiation. But because the photoelectric emission is at the higher vapour pressure negligibly small compared with the positive ion current itself, the flat portion of the curve becomes remarkable. Langmuir obtained curve 3 for the metallic Cs ($P = 5.9 \times 10^{-10}$ mmHg. $T = 39.9^\circ\text{C}$).

But at the higher pressure of the Cs₂O-Cs system, we obtained the results as shown in Fig. 4. which is of quite different nature. If the photoelectric emission from the ion collector were extremely large as compared with the ion current, such a curve should be obtained. But, from this reason, we can not understand, why the current varies exponentially against the bulb temperature.

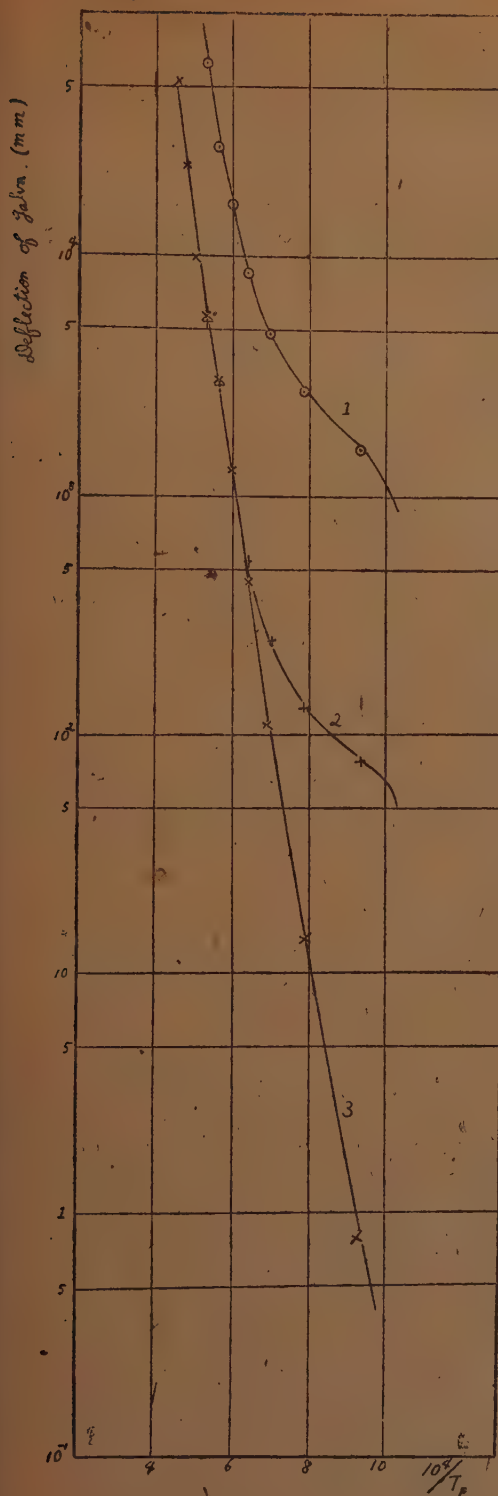


Fig. 4. Cs/O=3.5.

Curve 1 145°C.

Curve 2 110°C.

Curve 3 60°C.

On the other hand, if the vapour pressure is due to the molecules, whose ionization potential φ is somewhat greater than the electron affinity χ of the tungsten metal, the ion current will vary against T_F as shown in Fig. 4. When such a molecule impinges on the hot filament of tungsten, it is ionized with the relative probability $\exp(\chi - \varphi/kT_F)$. Consequently if $\chi > \varphi$ the ion current varies exponentially for $1/T_F$, and the tendency of the curve in Fig. 4 is explained. These molecules may be the suboxide of Cs such as Cs_2O . But we know nothing precisely about these points, which are the subject of the coming investigation.

References.

- (1) I. Langmuir: Phys. Rev. **51** (1937), 753.
- (2) This fact was discovered at first by Campbell's pioneer work and confirmed more precisely by M. Suda and others.
N. R. Campbell: Phil. Mag. **12** (1931), 173.
M. Suda, and others: Toshiba Kenkyu Jiho (in Jap.) **19** (1944), 100.
- (3) S. Asao: Proc. Phys. Math. Soc. Jap. **22** (1940), 448.
K. Noga: Toshiba Kenkyu Jiho (in Jap.) **19** (1944), 201.
- (4) I. Langmuir: Phys. Rev. **51** (1937), 753.
- (5) A. Kobayasi: Proc. Phys. Math. Soc. Japan, **25** (1943), 694.

On Atomic Energy Levels of $p^n l$ Configurations.

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1. INTRODUCTION AND SUMMARY.

The energy expressions of $p^n p$ and $p^n d$ configurations in single-body approximation for LS -coupling case have been found already⁽¹⁾. We have in this paper, instead of carrying out similar calculations for $p^n f$ and so on, sought the general expressions of the energies for the configurations, in which an l electron is attached to the core of p^n . When more than two states with equal (L, S) arise, the rows and columns of the energy matrix are labelled by the states (L', S') of the core, i.e. the parent terms. This has the advantage that the diagonal elements give approximately the energies of the terms expressed spectroscopically by $L, S (L', S')$. Moreover, it is practically impossible to express the individual energies explicitly as the roots of the secular equation of high degree, unless all the matrix elements are known numerically.

Since the method of calculation differs little from those described previously by the authors⁽¹⁾⁽²⁾, the details will be omitted. In short, we construct the energy matrix by the sets of orbitals with $\sum m=0$, for the state having the resultant spin S . At the same time, our method attributes definite $S'=S\pm 1/2$ to every rows and columns. Finally we transform this matrix into the scheme having definite L and L' values.

It is necessary to find the energies resulting from the addition of the last l electron only, since the energies of p^n are already known.

For the calculation of the direct and the exchange integrals contained in these expressions, we need the values of

$$c^i(lm, lm'), \quad (|m-m'| \leq 2) \\ c^{i-1}(1\mu, lm), \quad c^{i+1}(1\mu, lm), \quad (|\mu| \leq 1)$$

for which the general expressions have been found in a previous paper⁽³⁾.

2. ENERGY EXPRESSIONS.

By omitting the energy common to $p^n l$ as well as those of p^n , the elements of the energy matrix have the form:

$$aF^i(p, l) + bG^{i-1}(p, l) + cG^{i+1}(p, l)$$

where F^i , G^{i-1} , and G^{i+1} are certain integrals involving the radial parts of the orbitals (Slater's parameters). We shall write the above elements as

$$\alpha F_2 + \beta G_{l-1} + \gamma G_{l+1}$$

by introducing

$$F_2 = \frac{F^2}{5(2l-1)(2l+3)},$$

$$G_{l-1} = \frac{3G^{l-1}}{2(2l+1)(2l-1)^2},$$

$$G_{l+1} = \frac{3G^{l+1}}{2(2l+1)(2l+3)^2},$$

and express the final results by the coefficients α, β, γ . (F_2, G_{l-1} , and G_{l+1} here employed differ in some case by constant factors from the quantities with the same notations of Condon and Shortley.) For many-dimensional matrices (L', S') of the core are put before the rows of the energy matrices. (We have written the multiplicities $\mu=2S+1$ and $\mu'=2S'+1$ instead of S and S' according to the usage.)

pl

${}^{\mu}L$	F_2	G_{l-1}	G_{l+1}
${}^3(l+1)$	$l(2l-1)$	$-2l(2l-1)$	-2
${}^3(l)$	$-(2l+3)(2l-1)$	$2(2l-1)$	$-2(2l+3)$
${}^3(l-1)$	$(l+1)(2l+3)$	-2	$-2(l+1)(2l+3)$
${}^1(l+1)$	$l(2l-1)$	$2l(2l-1)$	2
${}^1(l)$	$-(2l+3)(2l-1)$	$-2(2l-1)$	$2(2l+3)$
${}^1(l-1)$	$(l+1)(2l+3)$	2	$2(l+1)(2l+3)$

$$p^1l$$

^pL	F_2	G_{l-1}	G_{l+1}
$^4(l+1)$	$-l(2l-1)$	$-2l(2l-1)$	$-4(l+1)$
$^3(l)$	$(2l+3)(2l-1)$	$-2l(2l-1)$	$-2(l+1)(2l+3)$
$^3(l-1)$	$-(l+1)(2l+3)$	$4l$	$-2(l+1)(2l+3)$
$^2(l+2)$	$2l(2l-1)$	$-2l(2l-1)$	-2
$^2(l-2)$	$-2(l+1)(2l+3)$	-2	$-(l+1)(2l+3)$

 $^2(l+1)$

	F_2	
^3P	$-l(2l-1)$	0
^1D	0	$-(l+6)(2l-1)$

 G_{l-1}

^3P	$l(2l-1)$	$(2l-1)\sqrt{3l(l+2)}$
^1D	$(2l-1)\sqrt{3l(l+2)}$	$-(l-2)(2l-1)$

 G_{l+1}

^3P	$2(l+1)$	$-2\sqrt{3l(l+2)}$
^1D	$-2\sqrt{3l(l+2)}$	$-2(l+3)$

 $^1(l)$ F_2

^3P	$(2l+3)(2l-1)$	0	0
^1D	0	$-(2l+5)(2l-3)$	$2\sqrt{2l(l+1)(2l+3)(2l-1)}$
^1S	0	$2\sqrt{2l(l+1)(2l+3)(2l-1)}$	0

 G_{l-1}

^3P	$l(2l-1)$	$(l-2)\sqrt{(2l+3)(2l-1)}$	$(2l-1)\sqrt{2l(l+1)}$
^1D	$(l-2)\sqrt{(2l+3)(2l-1)}$	$-(2l^2-13l+12)/3$	$-\sqrt{2l(l+1)(2l+3)(2l-1)}/3$
^1S	$(2l-1)\sqrt{2l(l+1)}$	$-\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-2l(2l-1)/3$

 G_{l+3}

^3P	$(l+1)(2l+3)$	$(l+3)\sqrt{(2l+3)(2l-1)}$	$-(2l+3)\sqrt{2l(l+1)}$
^1D	$(l+3)\sqrt{(2l+3)(2l-1)}$	$-(2l^2+17l+27)/3$	$-\sqrt{2l(l+1)(2l+3)(2l-1)}/3$
^1S	$-(2l+3)\sqrt{2l(l+1)}$	$-\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-2(l+1)(2l+3)/3$

 $^2(l-1)$ F_2

^3P	$-(l+1)(2l+3)$	0
^1D	0	$-(l-5)(2l+3)$

G_{l-1}

${}^3P$	$-2l$	$-2\sqrt{3(l^2-1)}$
${}^1D$	$-2\sqrt{3(l^2-1)}$	$2(l-2)$

 G_{l+1}

${}^3P$	$(l+1)(2l+3)$	$-(2l+3)\sqrt{3(l^2-1)}$
${}^1D$	$-(2l+3)\sqrt{3(l^2-1)}$	$-(l+3)(2l+3)$

 p^3l

${}^3L$	F_2	G_{l-1}	G_{l+1}
${}^3(l)$	0	$-2l(2l-1)$	$-2(l+1)(2l+3)$
${}^3(l+2)$	0	$-2l(2l-1)$	$-4(l+1)$
${}^3(l-2)$	0	$4l$	$-2(l+1)(2l+3)$
${}^3(l+1)$			

 F_2

${}^1D$	0	$-3(2l-1)\sqrt{l(l+2)}$
${}^2P$	$-3(2l-1)\sqrt{l(l+2)}$	0

 G_{l-1}

${}^1D$	$-2l(2l-1)$	0
${}^2P$	0	$-2l(2l-1)$

 G_{l+1}

${}^1D$	$-(2l^2+9l+6)$	$(2l+1)\sqrt{l(l+2)}$
${}^2P$	$(2l+1)\sqrt{l(l+2)}$	$-(2l^2+5l+4)$

 ${}^3(l)$ F_2

${}^4S$	0	0	0
${}^2D$	0	0	$3\sqrt{3(2l+3)(2l-1)}$
${}^2P$	0	$3\sqrt{3(2l+3)(2l-1)}$	0

 G_{l-1}

${}^4S$	$2l(2l-1)/3$	$4\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-4(2l-1)\sqrt{2l(l+1)}/3$
${}^2D$	$4\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-(10l^2-11l-3)/3$	$-(l+1)\sqrt{(2l+3)(2l-1)}/3$
${}^2P$	$-4(2l-1)\sqrt{2l(l+1)}/3$	$-(l+1)\sqrt{(2l+3)(2l-1)}/3$	$-(l-1)(2l-1)$

 G_{l+1}

${}^4S$	$2(2l+1)(2l+3)/3$	$2\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$2(2l+3)\sqrt{2l(l+1)}/3$
${}^2D$	$2\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-(10l^2+31l+18)/3$	$l\sqrt{(2l+3)(2l-1)}/3$
${}^2P$	$2(2l+3)\sqrt{2l(l+1)}/3$	$l\sqrt{(2l+3)(2l-1)}/3$	$-(l+2)(2l+3)$

$^3(l-1)$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 F_2 & \\
 \begin{array}{cc}
 0 & 3(2l+3)\sqrt{l^2-1} \\
 3(2l+3)\sqrt{l^2-1} & 0
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l-1} & \\
 \begin{array}{cc}
 -2l^2+5l+1 & -(2l+1)\sqrt{l^2-1} \\
 -(2l+1)\sqrt{l^2-1} & -2l^2+l-1
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l+1} & \\
 \begin{array}{cc}
 -2(l+1)(2l+3) & 0 \\
 0 & -2(l+1)(2l+3)
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^1L \\
 {}^1(l+2) \\
 {}^1(l-2) \\
 {}^1(l+1)
 \end{array}
 \begin{array}{ccc}
 F_2 & G_{l-1} & G_{l+1} \\
 \begin{array}{ccc}
 0 & -2l(2l-1) & 4l \\
 0 & -4(l+1) & -2(l+1)(2l+3)
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 F_2 & \\
 \begin{array}{cc}
 0 & -3(2l-1)\sqrt{l(l+2)} \\
 -3(2l-1)\sqrt{l(l+2)} & 0
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l-1} & \\
 \begin{array}{cc}
 4(2l-1) & 2(2l-1)\sqrt{l(l+2)} \\
 2(2l-1)\sqrt{l(l+2)} & 0
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l+1} & \\
 \begin{array}{cc}
 2l^2+5l-6 & -(2l+5)\sqrt{l(l+2)} \\
 -(2l+5)\sqrt{l(l+2)} & l(2l+1)
 \end{array}
 \end{array}$$

 $^1(l)$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 F_2 & \\
 \begin{array}{cc}
 0 & 3\sqrt{3(2l+3)(2l-1)} \\
 3\sqrt{3(2l+3)(2l-1)} & 0
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l-1} & \\
 \begin{array}{cc}
 2l^2+5l-9 & (l-1)\sqrt{3(2l+3)(2l-1)} \\
 (l-1)\sqrt{3(2l+3)(2l-1)} & -(l+1)(2l-1)
 \end{array}
 \end{array}$$

$$\begin{array}{c}
 {}^3D \\
 {}^3P
 \end{array}
 \begin{array}{cc}
 G_{l+1} & \\
 \begin{array}{cc}
 2l^2-l-12 & -(l+2)\sqrt{3(2l+3)(2l-1)} \\
 -(l+2)\sqrt{3(2l+3)(2l-1)} & -l(2l+3)
 \end{array}
 \end{array}$$

${}^1(l-1)$

$$F_2$$

${}^2D$	0	$3(2l+3)\sqrt{l^2-1}$
${}^2P$	$3(2l+3)\sqrt{l^2-1}$	0

$$G_{l-1}$$

${}^2D$	$2l^2-l-9$	$(2l-3)\sqrt{l^2-1}$
${}^2P$	$(2l-3)\sqrt{l^2-1}$	$(l+1)(2l+1)$

$$G_{l+1}$$

${}^2D$	$-4(2l+3)$	$-2(2l+3)\sqrt{l^2-1}$
${}^2P$	$-2(2l+3)\sqrt{l^2-1}$	0

p^l

${}^0L$	F_2	G_{l-1}	G_{l+1}
${}^4(l+1)$	$l(2l-1)$	$-2l(2l-1)$	$-2(l+1)(2l+3)$
${}^3(l)$	$-(2l+3)(2l-1)$	$-2l(2l-1)$	$-2(l+1)(2l+3)$
${}^2(l-1)$	$(l+1)(2l+3)$	$-2l(2l-1)$	$-2(l+1)(2l+3)$
${}^2(l+2)$	$-2l(2l-1)$	$-2l(2l-1)$	$-4(l+1)$
${}^2(l-2)$	$-2(l+1)(2l+3)$	$4l$	$-2(l+1)(2l+3)$

 ${}^2(l+1)$

$$F_2$$

${}^3P$	$l(2l-1)$	0
${}^3D$	0	$(l+6)(2l-1)$

$$G_{l-1}$$

${}^3P$	$-2l(2l-1)$	0
${}^3D$	0	$-2l(2l-1)$

$$G_{l+1}$$

${}^3P$	$l(2l+5)$	$-(2l+1)\sqrt{3l(l+2)}$
${}^3D$	$-(2l+1)\sqrt{3l(l+2)}$	$-(2l^2+9l+6)$

 ${}^2(l)$

$$F_2$$

${}^3P$	$-(2l+3)(2l-1)$	0	0
${}^3D$	0	$(2l+5)(2l-3)$	$-2\sqrt{2l(l+1)(2l+3)(2l-1)}$
${}^3S$	0	$-2\sqrt{2l(l+1)(2l+3)(2l-1)}$	0

G_{l-1}

^3P	$(l+3)(2l-1)$	$(l+1)\sqrt{(2l+3)(2l-1)}$	$(2l-1)\sqrt{2l(l+1)}$
^1D	$(l+1)\sqrt{(2l+3)(2l-1)}$	$-(10l^2-11l-3)/3$	$\sqrt{2l(l+1)(2l+3)(2l-1)}/3$
^1S	$(2l-1)\sqrt{2l(l+1)}$	$\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-4l(2l-1)/3$

 G_{l+1}

^3P	$2l^2-l-6$	$-l\sqrt{(2l+3)(2l-1)}$	$-(2l+3)\sqrt{2l(l+1)}$
^1D	$-l\sqrt{(2l+3)(2l-1)}$	$-(10l^2+31l+18)/3$	$\sqrt{2l(l+1)(2l+3)(2l-1)}/3$
^1S	$-(2l+3)\sqrt{2l(l+1)}$	$\sqrt{2l(l+1)(2l+3)(2l-1)}/3$	$-4(l+1)(2l+3)/3$

 $^2(l-1)$ F_2

^3P	$(l+1)(2l+3)$	0
^1D	0	$(l-5)(2l+3)$

 G_{l-1}

^3P	$(l+1)(2l-3)$	$(2l+1)\sqrt{3(l^2-1)}$
^1D	$(2l+1)\sqrt{3(l^2-1)}$	$-2l^2+5l+1$

 G_{l+1}

^3P	$-2(l+1)(2l+3)$	0
^1D	0	$-2(l+1)(2l+3)$

 p^5l

^pL	F_2	G_{l-1}	G_{l+1}
$^3(l+1)$	$-l(2l-1)$	0	0
$^3(l)$	$(2l+3)(2l-1)$	0	0
$^3(l-1)$	$-(l+1)(2l+3)$	0	0
$^1(l+1)$	$-l(2l-1)$	0	$4(l+1)(2l+1)$
$^1(l)$	$(2l+3)(2l-1)$	0	0
$^1(l-1)$	$-(l+1)(2l+3)$	$4l(2l+1)$	0

References.

This work is due to the Subsidy for the scientific researches of Education Department.

- (1) T. Yamānouchi, Proc. Phys.-Math. Soc. Japan, **20** (1938), 547; **21** (1939), 47. M. Masiko ibid. **20** (1938), 399.
 (2) A. Amemiya, J. Phys.-Math. Soc. Japan (in Jap.), **17** (1943), 567.
 (3) T. Yamānouchi and M. Masiko, J. Phys. Math. Soc. Japan (in Jap.), **17** (1943), 581.

Cloud Chamber Observation of Photo-alpha Particles Produced by 17 MeV Gamma Rays.

By

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(Received December 21, 1944.)

As it was previously reported, alpha particles seem to be generally expelled from various substances when they are irradiated by the gamma rays of high energies.⁽¹⁾ In that time, the emitted alpha particles were observed by a system of counting instruments which demanded, however, the careful adjustment and the personal skilfulness for the reliable experiment.

To make the experimental confirmation of the observed phenomenon conclusively, further observations have been done by using a cloud chamber of relatively longer acting period, which had been constructed by M. Sonoda⁽²⁾ before he started to the front.

We are now to give a short account of the result in the following.

In front of the lithium target bombarded with a current of $70 \mu\text{A}$ of 500 KeV protons, the cloud chamber was set so as a lead plate of 1 mm thick and 8 cm $\times$ 3 cm wide inserted in the chamber is placed at a distance of 22 cm. The gamma rays from the target were filtered by a lead cylinder 1.4 cm thick and then, in most cases, collimated by passing through a hole of 1 cm in diameter made in a lead block of 9 cm thick. The photograph of tracks was taken every time in an exposure of the next $1/8$ sec. following the $1/4$ sec. elapsed after the expansion, meanwhile the lithium target was continuously bombarded by high speed protons. 236 plain films were obtained for examination in good conditions.

Most of them showed certainly the tracks of electrons due to Compton effect, the pair production effect and etc. of the 17 MeV gamma quanta, but four films in all contained the track of an alpha particle in each case respectively, and namely three originated from the surface of the inserted lead plate and one from the glass wall of the chamber. The ranges R of the particles and the angles θ which the tracks

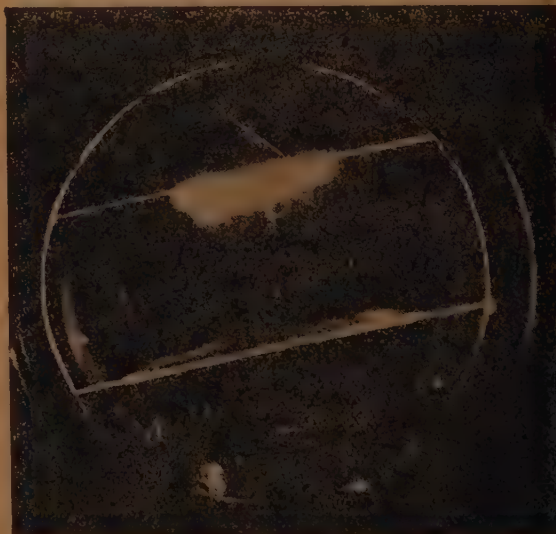


Fig. 1 $h\nu$ (17 MeV)
Photo-alpha particle.

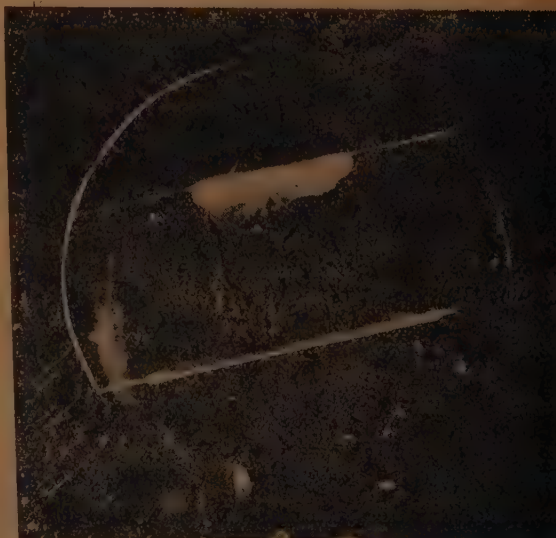


Fig. 2 $h\nu$ (17 MeV)
Not yet fully explainable track, photo-proton or one of the heavy electrons or charged mesons.

of the emitted particles apparently made with the direction of the incident gamma rays are as shown in Table I.

Table I.

Film No.	R	E	θ
15	2.3 cm	3.8 MeV	+144°
161	3.2	4.7	+163
233	>1.0	>1.9	-174
198	1.4	2.0	+78

The positive (negative) sign indicates that the particle is emitted to the right (left) hand side of the incident direction of the gamma rays.

If we neglect the energies lost in the lead plate, we see that the energies of the emitted particles E lie in the region between 1.9 MeV and 4.7 MeV.

Now, the net integrated duration of the time effectively exposed to the 17 MeV gamma rays for the production of photo-particles under observation is about $(1/4 + 1/8) \times 236 = 86$ sec. and the observed number of the tracks of alpha particles are 4. This is about the number of the right order of the magnitude in comparison with the observed number of counts in the previous experiment.⁽¹⁾

One might suspect, however, that the observed tracks of alpha particles were not those induced by the irradiation of the gamma rays, but rather they were entirely due to the radioactive substances contaminated on the surface of the lead plate or on the glass wall of the chamber.

But we see this can not be the case, for, when about 2000 expansion photographs were similarly taken in the absence of the 17 MeV gamma radiation no tracks of alpha particles issued from the lead plate, while, in total, three tracks of relatively longer ranges (about 3 cm–4.5 cm) were observed originated from the glass wall of the chamber.

We may conclude in this way that some or most of the observed tracks of alpha particles

issued from the lead plate are due to the photo-effect of the 17 MeV gamma rays, and hence the photo-alpha effect pointed out in the previous paper.

The more intense source of radiation is necessary for the further confirmation of the named effect.

Remarks:—

Beside the tracks of the photo-alpha particles and those of the electrons due to Compton effect and pair production effect of the quanta, we observed one straight but thin track originated from the glass wall of the chamber directly faced to the target and ended apparently at the surface of the lead foil after passing through 3.9 cm in air in the chamber. From the density of the droplets, we may take the track to be in the most probability, due to a proton of the energy between 1.4 MeV and 7.6 MeV. We may, however, alternatively account that it owes to an alpha particle passing, by chance, through the space of faint illumination in the chamber, and possessed of the energy estimated greater than 5.4 MeV. The value becomes less than 1 MeV if we assume that the particles is one of the heavy electrons⁽²⁾ or charged mesons⁽⁴⁾ of the mass hundred times greater than an ordinary electron. As for the discussion about the nature of the particle, it is to be reserved until more experimental data are obtained.

In conclusion, the authors acknowledge their indebtedness to the defray of the Scientific Research Expenditure from the Department of Education.

References.

- (1) B. Arakatsu and others. Proc. Phys.-Math. Soc., Japan, 25 (1943), 173.
- (2) M. Sonoda. The report will be done in elsewhere.
- (3) B. Arakatsu, Memoirs of the Fac. of Science and Agriculture, Taihoku Imp. Univ. Vol. V, (1932), No. 5.
- (4) H. Yukawa, Proc. Phys.-Math. Soc., Japan, 17 (1935), 48.

On the Photo-electric Quantum Efficiency of Geiger-Mueller Counters for X-ray Intensity Measurements.

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(Received August 26, 1946.)

1. INTRODUCTION.

The usefulness of Geiger-Mueller counters for counting charged particles and photons is well known. Besides their applications to the problem of cosmic rays and radioactivity, they have been adapted for X-ray studies.

The work reported here concerns the use of the counter for measurement of feeble X-ray intensities, by means of the photo-electric action of the X-ray on the gas and cathode metal of the counter. In the experiments described here, almost monochromatic X-rays are used. The photo-electric quantum efficiency of the counter has been determined from the following two counting rate measurements, the first one made with the monochromatic X-ray beam passing only through the gas filling the counter, and then the second with the beam passing through the gas and striking the cathode metal which ejects electrons from the surface.

If besides ejecting electrons from the cathode metal surface the incident X-ray photon possesses sufficient energy to produce secondary radiation,

which in turn might eject electrons from either the gas or cathode metal, the chance of counting such a photon might be increased.

2. THE COUNTER.

Fig. 1. (a) and (b) respectively show the longitudinal and lateral cross section of the counter.

The cathode is a brass cylinder 1.7 cm in diameter and 3.5 cm long, and wire electrode is of bare tungsten, 0.1 mm in diameter.

As illustrated in Fig. 1. (b) there are three drilled windows at the center of brass cylinder the one is entrance and the other two exits of the X-ray. A narrow X-ray beam enters the counter through the small entrance window of very thin mica and passes through the counter across the center of the cylinder in such a way as to miss or strike the back cathode metal or wire electrode.

The gas consists of 1/6 alcohol and 5/6 argon at 60 mm Hg. The insulating material between brass cylinder and wire electrode is amber.

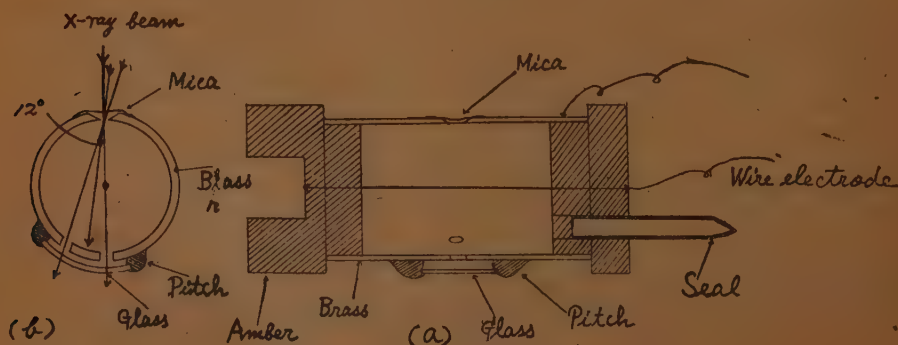


Fig. 1. Diagram of counter.

3. EXPERIMENTAL APPARATUS.

The circuit used for amplifying and recording the counter impulse consists of scale-of-16 circuit.

The Geiger-Mueller counter is coupled to the first amplifying tube UZ-57 through 25 μF condenser and grounded through 10 Meg ohms. The scale-of-16 circuit employs many UY-56 tubes. One of the last UY-56 tube feeds its impulse into a type thyratron TY-15G tube which operates a mechanical counter. The high voltage supply is obtained from a rectifier of the type designed by Street & Johnson, and its fluctuation constant was less than 0.1 percent.

Fig. 2. shows the source of X-ray and the arrangement of experimental apparatus. The characteristic X-ray radiation $\text{FeK}\alpha$ (1.934 A), $\text{CuK}\alpha$ (1.54 A) and $\text{MoK}\alpha$ (0.71 A) produced from Fe, Cu, Mo target are monochromatised by well known filter methodes. A series of thick lead blocks with S_1, S_2, S_3 holes of suitable diameter in 0.5 mm as shown in Fig. 2. mounted between the X-ray source and the counter tube, restricts the incident X-ray beam to a size sufficiently smaller than the diameter of the counter window in order that none of the radiation passing through it will strike the cathode metal.

This is accomplished by sighting a small holes of the counter through collimating holes S_1, S_2, S_3 which is illuminated with a bright light placed at X-ray source. X-ray beam will strike the counter cylinder at the exit, by the slight rotation of the counter at the needle point K. (Fig. 2.).

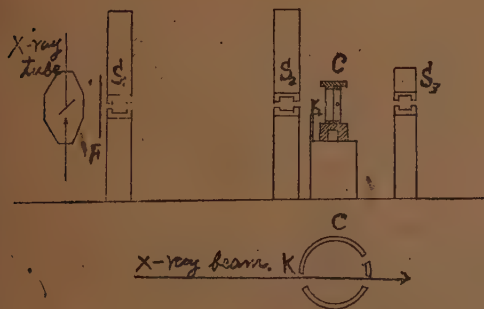


Fig. 2. Arrangement of experimental apparatus.
C: Counter. F: Filter. $S_1 S_2 S_3$: Slit.

4. PRELIMINARY TEST.

It is well known that the production of X-ray

depends upon the tube current and tube voltage in the following manner

$$I = K(V - V_c)^n i$$

Where I = the X-ray beam intensity,

i = the X-ray tube current,

V = the voltage drop across the X-ray tube,

V_c = the voltage necessary to excite the series,

K = proportional constant,

and n is a constant. (about 1.8~2)

In order to make counter test of this relationship, the counter received these characteristic radiation.

Fig. 3 shows the typical counting rates ob-

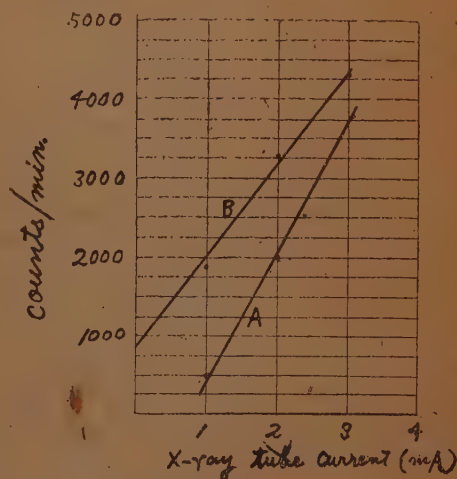


Fig. 3. Counting rate for $\text{MoK}\alpha$ at constant voltage (33-KV).

Curve A: X-ray beam passing only through the gas.

Curve B: X-ray beam passing through the gas and striking the cathode metal.

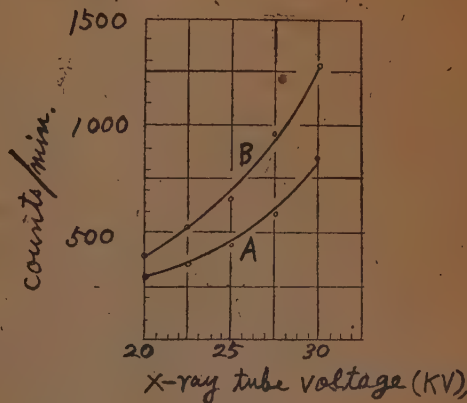


Fig. 4. Counting rate for $\text{MoK}\alpha$ at various voltage, where the tube current is constant. (1 mA).

served as the Mo-target X-ray tube current is varied, the voltage drop across the X-ray tube being held constant. (33,000 V).

Fig. 4 shows the counting rates as the X-ray tube voltage is varied, the tube current being held constant. (1 mA).

In Fig. 3, or 4, curves A and B have been determined respectively from counting with the X-ray beam passing only through the gas filling the counter or with the beam passing through the gas and striking the cathode metal. From these data the measurement of the exponential $n=1.8$ has been determined by plotting log counting rates against log voltage.

The absorption coefficients of the Sakura X-ray film, and black paper which covered it, or aluminium are also measured by the same methods above mentioned. These data are shown in Table I.

Table I. Absorption Coefficient of various material for FeK α , CuK α , MoK α .

μ Wave length	Black paper	X-ray film	Aluminium $\frac{\mu}{\rho}$	Aluminium $\frac{\mu^*}{\rho}$
FeK α (1.934A)	7.5cm ⁻¹	24cm ⁻¹	88	93.5
CuK α (1.54A)	5 cm ⁻¹	21cm ⁻¹	45	49
MoK α (0.71A)	1.8cm ⁻¹	14.6cm ⁻¹	6	5.2

$\frac{\mu^*}{\rho}$: A.H. Compton, S.K. Allison.

"X-ray in Theory and Experiment p. 800".

5. QUANTUM EFFICIENCY OF THE COUNTER.

Generally the fraction of the X-ray absorbed in the gas filling the counter is calculated on the basis of the wave-length, the pressure and constitution of the gas, and the length of the path in the counter.

In argon and alcohol the scattering coefficient may be neglected, as compared with the photo-electric absorption coefficient. The photo-electric absorption coefficient of the gas is calculated as in the following manner:

$$\tau_a = \frac{\mu}{\rho} \frac{A}{N} \dots \dots \dots (1)$$

or from the formula of B. Walter

$$\tau_a = 2.64 \times 10^{-26} Z^{3.94} \lambda^3 \dots \dots \dots (2)$$

($\lambda < \lambda_K$ K-absorption limit)

where τ_a =photo-electric absorption coefficient,

$\frac{\mu}{\rho}$ =mass absorption coefficient,

N =Loschmitt number 6.064×10^{23} ,

A =atomic weight,

Z =atomic number,

λ =wave-length.

The number of atoms per c.c. in the gas filling the counter (1/6 alcohol, 5/6 argon at 60 mmHg at 20°C) is 2×10^{18} . The absorption path in the counter is 1.65 cm.

When the beam of X-ray passes only through the gas of the Geiger-Mueller counter, there is a one-to-one correspondence between the number of photo-electric absorption events in the counter and the number of impulses recorded, i.e. the quantum efficiency, namely the fraction of X-ray photon absorbed may be computed from known gas absorption coefficient in the following manner:

$$Q_0 = \frac{n_1}{n} = 1 - e^{-\tau_a x N}$$

where n_1 =number of counts recorded,

n =number of photon in X-ray beam,

τ_a =photo-electric absorption coefficient of the gas,

N =number of atoms per cubic centimeter of gas,

x =length of path of X-ray beam in the counter.

Knowing this fraction Q_0 , the number n of photons in the X-ray beam may be computed. The beam is then allowed to fall upon the brass cylinder of the counter at the exit, the increase in number of counts n_2 may be observed.

Table II. The values of quantum efficiency of the two typical test counters.

λ	No.	Q_0 (%)	n_1	n_2	Q_p (%)	Q_c (%)
FeK α (1.934A)	1	4.35	2987	4061	1.56	5.9
	2	4.35	2403	3308	1.64	6.0
CuK α (1.54A)	1	2.18	2800	3883	0.85	3.0
	2	2.18	2576	3312	0.63	2.8
MoK α (0.71A)	1	0.24	683	1291	0.21	0.45
	2	0.24	608	1248	0.25	0.49

Note: N_0 : Counter number.

Q_0 : Quantum efficiency computed from $1 - e^{-\tau_a x N}$.

n_1 : Observed counts/mip. with the beam passing only through the gas.

n_2 : Observed counts/min. with the beam passing through the gas and striking the cathode.

Q_p : Photo-electric quantum efficiency.

Q_c : Quantum efficiency on the condition of X-ray beam falling upon the cathode metal.

ved, because of the photo-electron ejection from the cathode metal surface. If the increased counting rate $n_2 - n_1$ is divided by n , the fraction $Q_p = \frac{n_2 - n_1}{n}$ or $Q_p = \frac{(n_2 - n_1)}{n_1} \cdot Q_0$ means the "photo-electric" quantum efficiency of Geiger-Mueller counter, and the fraction $Q_c = \frac{n_2}{n} = \frac{n_2 Q_0}{n_1}$ means the quantum efficiency of the counter on the condition of the beam passing through the gas and striking the cathode metal. Table II shows the value of quantum efficiency Q_0 , Q_c , Q_p , with the observed counting per minutes for two representative test counters. As illustrated in the second chapter, the experiment in which the beam passes through the gas filling the counter and strikes only tungsten wire electrode is tried, but particularly increased counting rate is not observed, namely the photo-electric quantum efficiency on the wire electrode is not observed.

6. RESULTS AND DISCUSSIONS.

The photo-electric quantum efficiency Q_p of Geiger-Mueller counter filling argon and alcohol gas have been determined to be about 1.56 ~ 1.64 % (for FeK α), 0.63 ~ 0.85 % (for CuK α), 0.21 ~ 0.25 % (for MoK α) for two or three test counters. The quantum efficiency Q_0 of the counter in the condition that the X-ray beam passing through the gas and striking the cathode metal, has been determined to be 5.9 ~ 6 % (for FeK α), 2.8 ~ 3 % (for CuK α), 0.45 ~ 0.49 % (for MoK α).

Above these experimental data on the photo-electric quantum efficiency (Q_p) are caused by the photo-electric absorption coefficient of the cylinder, therefore the ratio, for example in case of the counter No. 1,

$$Q_p(\text{FeK}\alpha) : Q_p(\text{CuK}\alpha) : Q_p(\text{MoK}\alpha) \\ = 1.56 : 0.85 : 0.21$$

is to be about the cube ratio of the wavelength, namely

$$\lambda^3(\text{FeK}\alpha) : \lambda^3(\text{CuK}\alpha) : \lambda^3(\text{MoK}\alpha) \\ = 7.19 : 3.54 : 0.35$$

According to equation 2.

From above mentioned value the fraction $\frac{Q_p(\text{CuK}\alpha)}{Q_p(\text{FeK}\alpha)} = \frac{0.85}{1.56}$ is roughly equal to 1/2, and also correspond to this value the fraction $\frac{\lambda^3(\text{CuK}\alpha)}{\lambda^3(\text{FeK}\alpha)} = \frac{3.54}{7.19}$ is roughly to be the same value. These relationship is clearly realized.

But the fraction $\frac{Q_p(\text{CuK}\alpha)}{Q_p(\text{MoK}\alpha)} = \frac{0.85}{0.21} \approx 4$ is not

correspond to the value $\frac{\lambda^3(\text{CuK}\alpha)}{\lambda^3(\text{MoK}\alpha)} = \frac{3.54}{0.35} \approx 10$, then there is large discrepancy in these data. This cause will be caused by the production of secondary characteristic radiation from the cathode metal, because the X-ray MoK α (0.71Å) which strikes the cathode metal excites the K series of brass cylinder.

If the quantum efficiency of Geiger-Mueller counter are clear by these experimental data above mentioned, the absolute energy measurement or the detection of feeble X-ray will be determined in the following manner,

$$E = \frac{n_1}{AQ} h\nu$$

or $n_1 = nQA \times 60 \geq 3\sqrt{B}$

where E = energy density of X-ray beam,

Q = quantum efficiency,

A = area of the cross section of X-ray beam,

n_1 = number of counts recorded per min.

ν = frequency,

n = number of photons per second falling in unit area,

h = Planck constant,

B = dark counts per min. by unknown radiation.

7. CONCLUSION.

A special Geiger-Mueller counter for measuring the X-ray intensity of known wave length is described. The absorbing gas filling the counter is alcohol at 10 mm Hg pressure and argon at 50 mm Hg. The cathode metal of the counter is brass cylinder 1.7 cm in diameter and 3.5 cm long. The photo-electric quantum efficiency Q_p of a Geiger-Mueller counter for X ray of known wave length FeK α , CuK α , MoK α , has been determined to be 1.56 ~ 1.64 %, 0.63 ~ 0.85 %, 0.21 ~ 0.25 %, respectively by the method with the beam passing only through the gas filling the counter, and then with the beam passing through the gas and striking the cathode metal.

At the preliminary test of the test counter the total absorption coefficient of the Sakura X-ray film and its black paper for the FeK α , CuK α , MoK α , are found as shown in Table I.

ACKNOWLEDGEMENTS.

The author wishes to express his appreciation and thanks to Dr. Y. Toriyama, and Dr. H. Hamada for the suggestion of the problem and for their discussion and guidance during the course of the investigation.

SHORT NOTES

ON THE SPECTRUM OF THE SOLAR CORONA AT THE TOTAL ECLIPSE IN 1943.

I. ON THE CORONAL LINES.

By Tutomu TANAKA, Hirobumi OURA,
Tosio MURAKAMI and Takio MITUNOBU.

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(Received March 6, 1945.)

The total eclipse of February 5, 1943, gave a chance to observe a minimum type of the solar corona. The station adopted by our party was a hill near Yubetu, Hokkaido.

In the first place, for the middle corona the intensity distributions of the coronal lines of $\lambda 5303 \text{ \AA}$ and $\lambda 6374 \text{ \AA}$ according to the distance from the sun's limb were investigated by photographic-photometry method. The intensity distributions for different lines as well as for different sides of the sun's limb are not common, though they do not make much difference from that of the continuous spectrum in the range of the distance from the sun's limb of $0.2r-0.4r$. For the distance from the sun's limb less than $0.2r$, the distribution curves of the coronal lines are flat, and deviate gradually from that of the continuous spectrum. The maximum of intensity exists at the distance of about $0.11r$ for $\lambda 5303 \text{ \AA}$ and of about $0.17r$ for $\lambda 6374 \text{ \AA}$ from the sun's limb.

Secondly, the wave-lengths of nine recorded coronal lines were measured with respect to the iron standard lines, and the following result was obtained:

3986.71 ± 0.01 , 4231.08 ± 0.01 , 4311.22 ± 0.01 ,
 4566.50 ± 0.02 , 5116.36 ± 0.02 , 5302.74 ± 0.01 ,
 5306.40 ± 0.03 , 6374.57 ± 0.03 , 6702.01 ± 0.06 in I.A.

The line of 5306.40 I.A. found in the spectrograms obtained in Syari, 1936, could clearly be found in the spectrogram of the present observation.

A more detailed report will be published in the near future in the Journal of the Faculty of Science of the Tokyo Imperial University.

ON THE SPECTRUM OF THE SOLAR CORONA AT THE TOTAL ECLIPSE IN 1943.

II. ON THE CONTINUOUS SPECTRUM.

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(Received March 6, 1945.)

At the total eclipse on Febr. 5, 1943, a two-prism spectrograph was used, of which behind the collimator lens a Wollaston quartz prism was put. By means of it the polarizability of the continuous spectrum of the solar corona was investigated.

For $0.6r < h < 1.3r$, the polarizability for each wave-length decreases gradually. Each polarizability curve does not much deviate from a straight line. The magnitude of the polarizability for each h decreases regularly as the wave-length increases. This deviation seems to be somewhat larger than the experimental error. But this variation might be due to the influence of intervening clouds. By reasonable assumptions, it can make the curves of different wave-lengths coincide with each other. The polarizability curve obtained thus is somewhat steeper than that due to Dufay and Grouiller, the value at $h=1.02r$ being equal in the both cases. At $h=0.5r$, the present result (40%) is nearly the mean of those by Cohn (54%) and Dufay-Grouiller (29%).

The total intensity distribution curves of different wave-lengths coincide with each other. The decay curves are somewhat steeper than those of the maximum type till the distance from the limb reaches some value and become flatter beyond this value.

The independency of the polarizability to the wave-length can perhaps be obtained from Cohn's data.

By adding the correction due to the effect of the sky light, the polarizability curve is raised by some few per cent, the slope of the curve decreasing slightly.

A more detailed account will be published in the near future in the Journal of the Faculty of Science of the Tokyo Imperial University.

SOLAR LIMB EFFECT OF SPECTRAL LINES IN A PROMINENCE OBSERVED AT THE TOTAL ECLIPSE IN 1941.

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At the total eclipse of the sun in 1941, the limb shift of spectral lines was investigated in a prominence situated on the east limb of the sun's equator. The wave-lengths of four hydrogen, two ionized calcium and two helium lines were carefully measured. And it was shown that for $H\beta$, $H\gamma$, $H\delta$, and the two helium lines no limb effect can be found. For $H\epsilon$ the same can perhaps be said too. But for H and K something exists that suggests the existence of the limb effect. Those amounts coincide with those found by Evershed without regard to the eclipses.

From the wave-lengths of $H\beta$, $H\gamma$, $H\delta$ and the two helium lines the radial velocity of the prominence due to the sun's sidereal rotation was proved to be 2.05 km/sec.

For $H\beta$, $H\gamma$ and $H\delta$ the centre defect of Fraunhofer lines seems to be within the range of experimental errors. For $H\epsilon$, H and K the wave-lengths of Fraunhofer lines in Tables seem not to be very exact. So any definite conclusion can hardly be deduced.

A more detailed account will be published in the near future in the Journal of the Faculty of Science of the Tokyo Imperial University.

ON THE PIEZOELECTRIC EFFECT OF ROCHELLE SALT CRYSTALS.⁽¹⁾

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(Received June 20, 1946.)

The voltage output of the transversal piezoelectric effect of rochelle salt crystal was examined under an alternating stress of 1 KC, and was found to be not much sensitive to the method of preparation of the crystal, and practically independent upon the temperature of the crystal except at the Curie point.

A thin square x -cut crystal plate, two sides of which are inclined 45° both with y and z axis, was prepared. A side was fixed, and the opposite face was attached to a longitudinally vibrating glass rod, the vibration frequency being electromechanically controlled. The alternating voltage appeared between two aluminum foils, stuck upon the surfaces of the crystal plate, was measured by a rectifier type vacuum tube voltmeter at different temperatures.

Six samples of crystals rendered from different manufacturers were examined. In all cases the voltage does not differ materially with different samples except at the Curie point, and it is of interest to note that even the sample obtained from aqueous solution containing 0.04 percent of Mg^{++} ions showed practically the same voltage output. Hence the use of such a substance as a facilitating agent for the growth of large crystals is justified.

At the Curie point the crystal shows a conspicuous maximum of the voltage output, amount of which varying with different samples.

In order to elucidate these phenomena, let us now analyse the behavior of the crystal at the Curie point. Putting the length of a side and the thickness of the plate a and b respectively, x -component of the electric polarisation, considered as a function of the electric field E and the shearing stress Y_z , can be written as

$$P = P_0 + \left(\frac{\partial P}{\partial E} \right)_0 E + \left(\frac{\partial P}{\partial Y} \right)_0 Y_z + \dots,$$

where $\left(\frac{\partial P}{\partial E} \right)_0$ is the electric susceptibility κ of the crystal without mechanical constraint. E is equal to V/b , where V is the voltage between two electrodes. If we express the normal force applied to the side plane by F , Y_z is equal to $F/2ab$, and since $\left(\frac{\partial P}{\partial Y_z} \right)_0$ is equal to the negative sign of the usual piezoelectric constant d_{14} , the electric charge which appears upon a surface of the crystal is

$$Q = \left(\kappa \frac{V}{b} - \frac{d_{14} \cdot F}{2ab} \right) a^2,$$

when both the electric field and the mechanical stress are considered to be small enough. As Q becomes also periodic, under the periodic force $F = F_0 \exp j2\pi ft$, the electric current I in the output circuit is equal to $j2fQ$, where $j^2 = -1$. Let the load impedance be Z , then $V = IZ$. Since κ is very large, it is nearly equal to $\frac{\epsilon}{4\pi}$, where ϵ is the dielectric constant of

the crystal without mechanical constraint. Taking these into consideration, the following relation is obtained:

$$V = IZ = j2\pi f QZ = j2\pi f \left(\frac{\epsilon}{4\pi} \frac{V}{b} - \frac{d_{14}F}{2ab} \right) aZ.$$

Solving this equation for V ,

$$V = \frac{-d_{14} \cdot 2\pi f a}{2b} FZ / \left(1 - j2\pi f Z \frac{\epsilon}{4\pi b} a^2 \right).$$

In a special case when Z is a pure resistance R ,

$$\begin{aligned} |V| &= \left| 2\pi f \frac{d_{14}a}{2b} FR / \left| 1 - j2\pi f R \frac{\epsilon}{4\pi b} a^2 \right| \right| \\ &= 2\pi \frac{d_{14}F}{\epsilon a} / \sqrt{1 + \left(\frac{1}{R2\pi f C} \right)^2}, \end{aligned}$$

where $C = \epsilon a^2 / 4\pi b$ is the capacity of the crystal plate.

If $\frac{d_{14}}{\epsilon}$ is almost independent upon the temperature as Mueller⁽¹⁾ says, the only variable that depends on the temperature is the capacity C of the crystal plate, which becomes large at the Curie temperature. Therefore when $R2\pi f C$ is small compared to 1, the voltage output is nearly equal to $R2\pi f C \cdot \frac{2\pi d_{14}F}{\epsilon a}$ and becomes maximum at the Curie temperature, whereas when $R2\pi f C$ is large compared to 1 the output is almost independent upon the temperature.

Summarising above discussions, it may be concluded that the voltage output does not depend so much upon the secondary structure of the crystal except at the Curie point, and its temperature dependence at the Curie point may be removed by increasing the load impedance and capacity of the crystal itself.

(1) A fuller account of this note was already published as a separate paper from the Physico-Mathematical Society of Japan in June, 1945. (In Japanese).

(2) Mueller: Phys. Rev. 58 (1940), 570.

ON POLYMORPHIC CHANGE OF BaTiO_3 .

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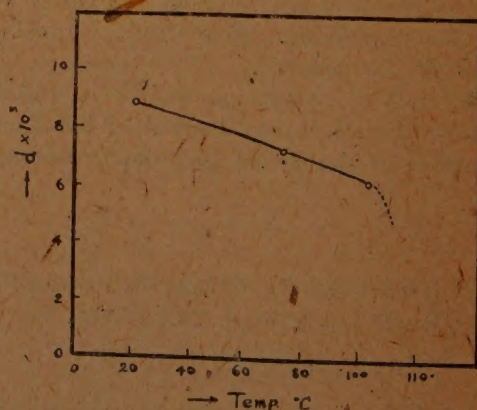
In 1944 Ogawa⁽¹⁾ discovered a remarkable dielectric property of barium titanate, BaTiO_3 . At room temperatures, this substance possesses a considerably high dielectric constant K , about 2000, but the most notable fact is that this

constant enormously increases with rising temperature and shows a very pronounced maximum at about 110°C , where K attains to such a high value as 8000 or more. This peak seems to correspond to some kind of the phase transition.

The present authors, offered a small quantity of the substance from Ogawa, performed an X-ray and thermal study on it, in a hope to obtain some informations about the nature of the supposed transition. The main result obtained will be now briefly described below.

(a) *X-ray analysis.* Hitherto, BaTiO_3 has been known as a cubic crystal with $a = 3.97 \text{ \AA}$. Now, powder photographs were taken using $\text{Co K}\alpha$. A back reflection camera was mainly utilized, in order to observe minute changes in the lattice constant. It was found a fact that at room temperatures most Debye lines are slightly splitted, forming multiplets. Namely, in room temperatures, BaTiO_3 is not a rigorous cubic structure, but rather it must be regarded as tetragonal, with lattice constants $a = 3.982 \text{ \AA}$, $c/a = 1 + d$, $d = 0.009$. d gradually approaches zero when temperature is raised, and the structure becomes completely cubic at about 110°C . In Fig. 1, the change of d with

Fig. 1



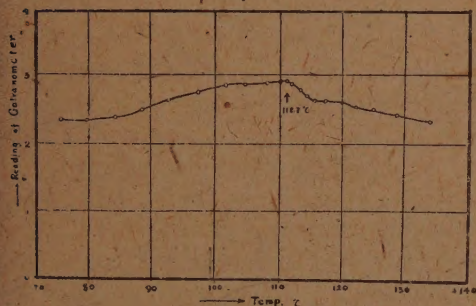
temperature is shown, which is obtained from the measurement on a multiplet corresponding to the cubic (510), (431)-line.

This figure shows that the change of the lattice takes place very continuously from room temperatures to 110°C . Except the split of lines as above mentioned, there was no appreciable difference in the line intensities for the high

temperature form (α), and the low temperature form (β).

(b) *Thermal analysis.* In order to ascertain the existence of some thermal anomaly, a calorimetric observation was performed by utilizing the differential caloric method. One of two cylindrical holes bored in a duralmin block was filled with BaTiO_3 of about 0.8 gr, and the other with a similar quantity of a mixture of TiO_2 and BaCO_3 as a control. The temperature difference of the two was measured with Ag-constantan thermo-junctions, and a galvanometer sensitivity, 4×10^{-7} volt/div). Heating speed was about $1.5^\circ\text{C}/\text{min}$. One of the heating curves obtained is reproduced in Fig. 2.

Fig. 2



It shows a slight but evident hump and a knick. From them we can conclude that the transition point is at $112.6 \pm 0.5^\circ\text{C}$. At almost the same temperature, a knick was observed in the cooling curve also.

The thermal anomaly as here observed seems to be due to an anomalous change of the specific heat in a wider temperature range. The latent heat at the transition point, if exists, is supposed to be exceedingly small. The relaxation phenomenon could not be noted. These facts seem to suggest that, it will be only a slight displacement of ions from the normal positions what takes place in the process of the transition.

More detailed results will be reported later on.

In conclusion we wish to express our cordial thanks to Mr. T. Ogawa, who gave us his precious sample according to our proposal.

(1) T. Ogawa: Unpublished yet.

(*) Very recently we are informed of an independent discovery by Mr. Vul in U. S. S. R.

(2) Strukturberichte, I, 333.

